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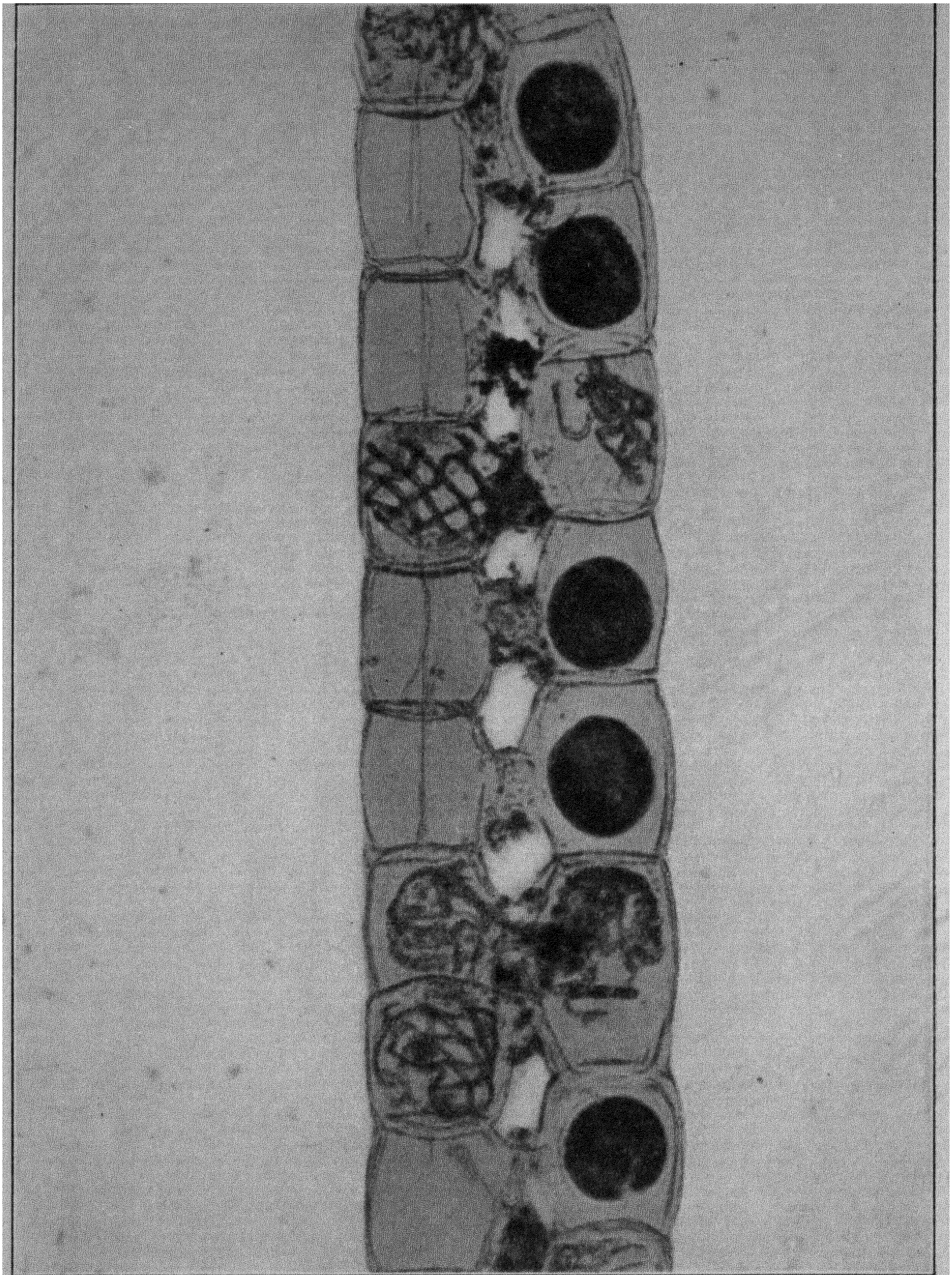
ELEMENTS OF PRACTICAL BIOLOGY



PHOTOMICROGRAPH SHOWING CONJUGATION BETWEEN TWO FILAMENTS OF *Spirogyra*

ELEMENTS OF PRACTICAL BIOLOGY

BY

A. P. GRAHAM, M.A. (Cantab.)

Biology Master, Clifton College

A Text-book covering the Syllabuses of the
Higher School Certificate and the Preliminary
Examinations for Medical and Dental Students
of the Universities and the Conjoint Board of
the Royal Colleges of Physicians and Surgeons

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THE TEMPLE PRESS, LETCHWORTH, HERTS
FIRST PUBLISHED 1933
LAST REPRINTED 1937

PREFACE

THIS book is an attempt to give clear and intelligible directions for practical work in Biology. The syllabuses covered are those of the Higher Certificate examinations and the first or preliminary examinations for medical and dental students of the Universities and the Conjoint Board of the Royal Colleges of Physicians and Surgeons.

The Introduction contains the essential and elementary details concerning the *modus operandi* in a biological laboratory, so that beginners will there find sufficient information to guide them in the way they should go. For the help of teachers and students working privately, appendices are included giving directions for the preparation of reagents and sources from which material can be obtained. Blank pages are included so that the book may record drawings made in accordance with the printed directions.

The order in which the types are set out follows the natural sequence of classification; but this order need not, and indeed cannot, be followed chronologically by the student in his practical work, since the seasons determine when a large proportion of the material will be available. It is hoped that the student will make frequent use of the Glossary of Technical Terms in order that the multitude of names with which he meets may not be utterly meaningless.

It is with the greatest pleasure that I acknowledge the help received in the preparation of this book. My thanks are due to Dr. Macgregor Skene, Professor of Botany, University of Bristol, for reading through and giving much help with the Botanical section; to Dr. J. T. Irving, Lecturer in Physiology, University of Bristol, for reading through the section on Biochemistry and giving much helpful criticism. Great care has been taken in the preparation of the Glossary; for the greater part of this I am indebted to my colleague Mr. W. R. Taylor, M.A. I am indebted to Professor A. G. Tansley, F.R.S., of the University of Oxford, for allowing me to adapt some of the directions for practical work from his book *Elements of Plant Biology*.

I have to thank Mr. P. Ullyott, of the Freshwater Biological Laboratory, Lake Windermere, who took the photomicrograph which forms the frontispiece; Mr. C. W. M. Whitty, who drew Fig. 34; and Mr. J. F. Marshall, Director of the British Mosquito Control Institute, who readily lent the blocks for Figs. 30 and 31.

Mr. E. Ford, of the Marine Biological Laboratory, Plymouth, kindly answered enquiries.

My thanks are due to the Oxford University Press and Dr. L. A. Borradaile for permission to reproduce Fig. 33 from his book *Manual of Zoology*; also to Messrs. William Watson and Sons for lending the block for Fig. 1. In conclusion, I should like to thank Dr. E. J. Holmyard, Head of the Science Department, Clifton College, for much invaluable advice, and without whose help in a great many ways this book would not have been possible.

A. P. GRAHAM.

CLIFTON COLLEGE

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INTRODUCTION

THE MICROSCOPE

THE microscope consists of three main parts, the condenser, the stage, and the tube with its object and eyepiece lenses. When carried about, the instrument should always be held by the arm, which is the main heavy part supporting the stage and tube.

The Tube. The eyepiece lens-systems most commonly used are marked ×6, ×8, or ×10, to indicate the number of times the eyepiece magnifies the image formed by the object lens. The focal length of the objective, which is made up of several lenses, determines the magnifying power. It is usual to employ objectives of focal lengths $\frac{2}{3}$ in. and $\frac{1}{6}$ in. For the instrument to be in focus it is obvious that the objective of focal length $\frac{1}{6}$ in. has to be placed nearer the object on the stage than the objective of $\frac{2}{3}$ in. focal length. The former objective is known as the 'high' power and the latter as the 'low' power.

For greater magnification an objective of focal length $\frac{1}{12}$ in. is used in conjunction with a drop of oil. This constitutes the oil immersion combination. By means of a glass rod one drop of cedar-wood oil is placed on top of the coverslip under which is the object to be magnified, and the tube of the microscope is lowered until the objective just touches the drop. On looking down the tube the instrument is further adjusted by lowering the lens into the oil until the image is clearly focused. Cedar-wood oil for this purpose has nearly the same refractive index as glass, and hence more light enters the objective from the object under observation than would do so if there were an air-space between the coverslip and the objective, owing to the refraction of light when passing from glass to air. The use of oil also avoids two partial reflections. This results in more light entering the tube and an increase in resolution.

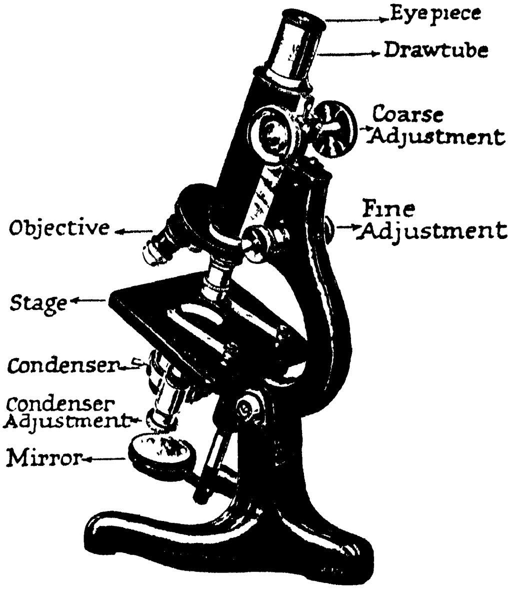

Fig 1. A modern microscope

The high-power objectives are made to work best with a definite tube length, and hence the distance between the objective and eyepiece can be adjusted by pulling out the draw-tube in which the latter fits. This adjustment makes very little difference with low-power objectives.

The Stage. Two clips are provided to hold a microscope slide in position. A mechanically controlled stage, which allows a preparation to be systematically explored, is a great advantage but by no means essential.

The Condenser. The object of the condenser is to focus light on to the specimen on the stage when it is to be viewed by transmitted light. For low-power work the condenser may be dispensed with. Indirect sunlight or a sixty candle-power opal electric bulb provides a good source of light. Superfluous light can be cut out by closing the iris diaphragm, and the intensity may be controlled by placing a translucent screen between the source of light and the reflecting mirror.

A source of white light is not always the best illuminant; for example a small light green organism when viewed in bright white light looks almost colourless and therefore indistinct. If a red screen is placed below the condenser, the organism appears black against a red background. When an object is being viewed under reflected light the condenser and mirror are not used.

MICROSCOPE ADJUSTMENT

The Condenser. First the condenser is lowered and the iris diaphragm nearly closed. The condenser is then adjusted until the small beam of light which is reflected from the mirror and passes through the opening in the diaphragm shines in the middle of the field when viewed through the tube. Secondly the iris diaphragm is opened and the condenser raised until the image of the illuminant can be clearly seen in the field; the optimum condition is when the condenser is slightly below this position.

The Tube. When the objective and eyepiece are in position, and the microscope slide is set on the stage, the tube is lowered until the objective just touches the cover-slip in the case of high power and to within $\frac{1}{2}$ in. of it when low power is being used. Whilst looking through the eyepiece the tube is then moved *away* from the slide until the object is in focus, first by using the coarse and then the fine adjustment screw. This prevents the tube being screwed down too far and boring through the slide.

An unknown preparation should always be viewed first under low power.

Measurement. The standard microscopic unit of measurement is 1 μ, or *micron* (=0·001 mm.). Measurement is effected by means of an eyepiece micrometer which fits into a Ramsden's eyepiece. The value of the scale engraved upon it varies with the combination of lenses used. The scale is calibrated for the required combination by focusing on to a slide which has divisions, $\frac{1}{100}$ mm., i.e. 10 μ, apart, scratched on it, and noting their relation with the divisions on the micrometer scale. The direct method of laying the micrometer inverted over the slide containing the object to be measured is not very accurate.

Cleaning. After use with oil immersion, the oil is removed from the lens with blotting-paper and the lens then wiped with blotting-paper soaked in benzene or xylol, and finally wiped dry with a clean wash-leather. Canada balsam can also be removed from a lens by this means. The lenses are easily scratched and should never be cleaned with a cloth or handkerchief. When the microscope is properly used the strain on the eyes is no greater than when reading a book. Give both eyes equal work and learn to look down the microscope tube keeping both eyes open.

INTRODUCTION

DRAWING

All drawings should be made first in pencil with firm, clear lines. The use of colours in a practical note-book is not desirable. The essential object is to show the structure of the parts studied, and shading should never be used except in drawing the general external view of a plant or animal; even then, important details such as the tympanic membrane on the outside of a frog's head should not be masked.

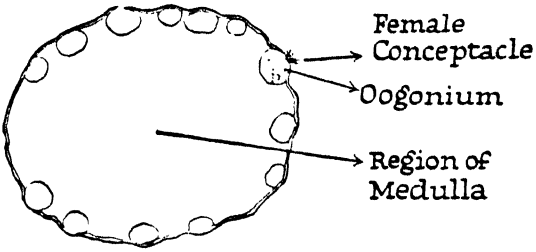

Fig. 2. Transverse section of fertile branch of *Fucus*, as seen under hand-lens

Drawings should always be large. A drawing showing the general structure of a transverse section through an earthworm should be at least $2\frac{1}{2}$ in. in diameter. A seta of an earthworm on the other hand, where no internal structure is to be represented, need only be drawn about 1 in. in length.

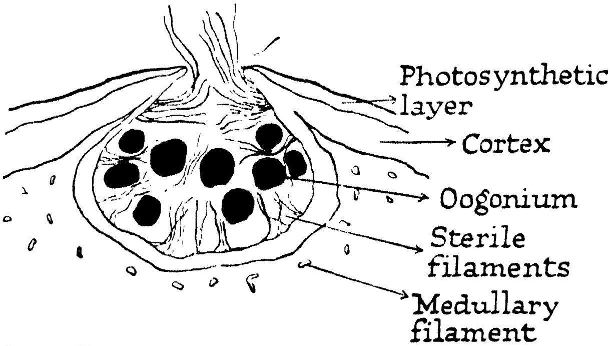

Fig 3. Female conceptacle of *Fucus*, as seen under low power of the microscope

All parts should be clearly labelled; repeated labellings of the same structure in different drawings is the surest way of learning new names. The names should be printed or written neatly and horizontally by the side of the drawing and connected to the respective parts by straight lines and arrows. If drawings of a female conceptacle of the seaweed are required, the first drawing should be a plan, merely showing in outline the relation of the important parts to one another (see Figs. 2–5). If the preparation is a large one, the first drawing can be made by viewing under a hand-lens.

One large drawing showing all the parts with hundreds of cells filled in should never be attempted; this would take far too much time to draw, would probably look very untidy when finished, and would almost certainly be inaccurate. Since you cannot represent every cell you see in such a large and detailed field accurately, without infinite labour, do not attempt it.

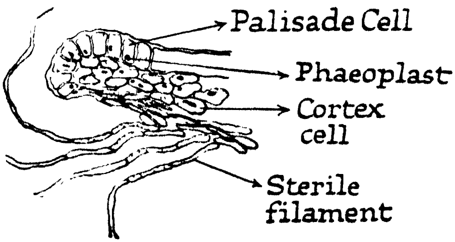

Fig. 4. Lining of female conceptacle of *Fucus*, as seen under high power of the microscope

Having shown the relations of the main parts, successive drawings should be made of the detailed structures by placing the preparation first under the low and then the high power of the microscope. Detailed drawings of small segments may be made in the same way (Fig. 16).

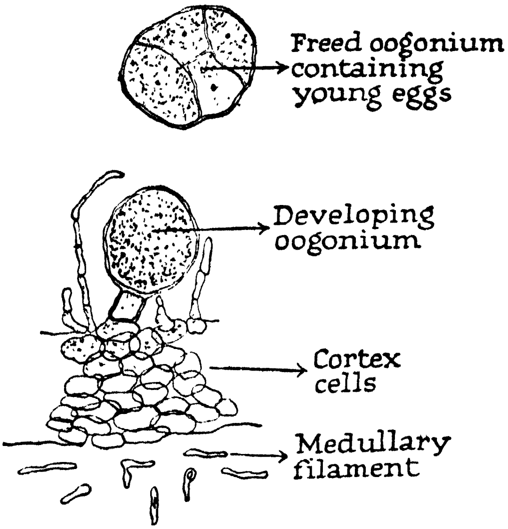

Fig. 5. Oogonia of *Fucus*, as seen under high power of the microscope

Draw only what can be seen; a student should never in a practical note-book rely on his knowledge or imagination to fill in details which he does not actually see. It is extremely unlikely that you will see in the first *Amoeba* studied under the microscope even the main structures that you know to be there. Your eye will be trained by constant use of the microscope just as surely as your hand will be by frequent dissections.

KILLING

Vertebrates should be killed by holding cotton-wool soaked in chloroform over the nostrils. Smaller animals may be immersed in chloroform. Marine animals may be killed by immersion in warm fresh water.

FIXING

The action of a fixing agent is to harden the material so that the cells retain their normal condition when further acted upon by stains. A fixing agent is also employed to prevent distortion or shrinkage of cell contents. A good fixing agent for animal tissues is a saturated solution of mercuric chloride (corrosive sublimate) in water, with acetic acid added to increase the penetration. Flemming's fluid is good for fixing plant tissues. For Protozoa a $\frac{1}{4}$ per cent solution of osmic acid in water is recommended. Tissues should not remain more than 5 min. in the fixing agent and should be thoroughly washed with water afterwards. Soft plant and animal tissues should be hardened, preparatory to cutting sections, by immersion successively in 50 and 70 per cent alcohols or in picric acid solution. Protozoa and other small organisms are best fixed and stained by keeping them in one watch-glass and changing the successive liquids by means of a pipette. The preparation is finally transferred to a microscope slide by means of a fine camel-hair brush, a needle, or a fine pipette.

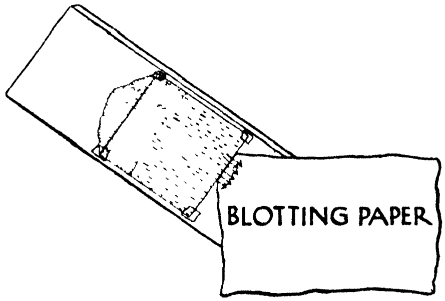

Fig. 6. Diagram of method of irrigation

Small organisms may be placed alive in a drop of water on a microscope slide and a coverslip supported over them by means of thin pieces of glass (broken-up coverslips) placed at the corners. Their reaction to any liquid or fixing agent can then be observed under the microscope by the method of irrigation. One drop of the liquid is placed one side of the coverslip and blotting-paper applied at the opposite side; this gradually soaks up the water from under the coverslip and draws in the liquid. A succession of liquids may be drawn under the coverslip by this method.

SECTION CUTTING

A *sharp* razor is absolutely essential for good section cutting. A razor-blade ground hollow on both sides is suitable for small sections, but a flat blade is necessary when cutting sections over a wide area. The blade should always be kept clean and stropped immediately before and after use.

A transverse section should be cut exactly at right angles to the main axis and a longitudinal section exactly parallel with it. A section cut obliquely is useless since the structures appear blurred and indefinite.

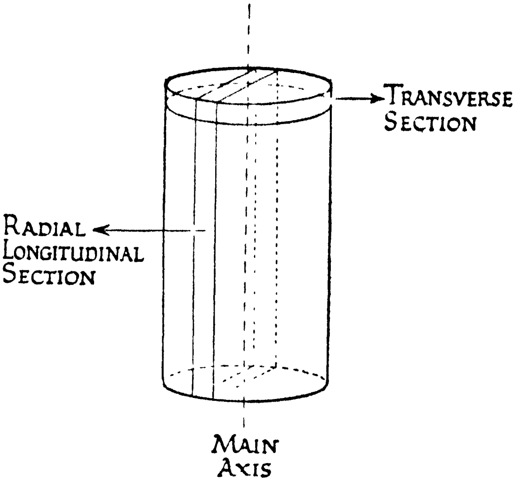

Fig. 7

A start may be made by cutting transverse sections from the root or stem of an herbaceous plant such as a bean seedling or from a piece of pith. A portion of the stem should be held between the thumb and first finger of the left hand. The razor is held in the right hand and a sliding cut made, utilizing a considerable length of the razor-blade. It makes no difference whether one cuts from left to right or vice versa. Do not attempt to cut right across the stem at the start and avoid thick, wedge-shaped sections.

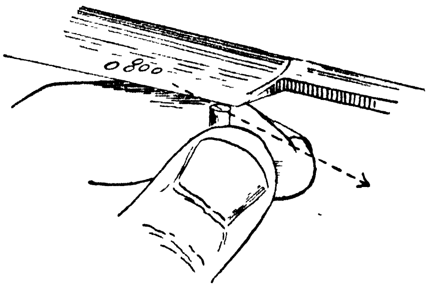

Fig. 8. Section cutting by hand

The stem and razor-blade should be thoroughly soaked in alcohol (30 per cent). This prevents the sections from drying and bubbles of air from appearing when the section is mounted: alcohol 'wets' the tissue more thoroughly than water. The sections which remain on the razor-blade can be washed off into a watch-glass for staining and further treatment. If the specimen is too small or fragile to be held without support, it can be held for section cutting in a piece of pith. A longitudinal groove is made down a piece of dried elder pith just wide enough to hold the specimen. The pith may be dipped in water, which causes it to swell slightly. It is then held as before and sections cut across the tissue with its supporting pith.

Very fragile tissue is embedded in soft paraffin wax (melting-point 40–45° C.). A cavity is made in the wax to hold the specimen in the required position and molten wax poured in to hold it firm. When the paraffin has set hard, sections may be cut; by this means the very fragile tissue is less likely to be damaged than when loosely held in pith. The paraffin is dissolved off from the section in xylol or turpentine. Beginners should learn to cut their sections by hand and should not rely on a microtome.

STAINING

Stains should be employed only for a definite purpose and not used merely to colour up a structure which is quite obvious without their aid.

A list of the more important stains for animal and plant tissues is given on pages 8, 9, and 10, with instructions for their use. The time during which a section is left in the stain depends on its strength; it is therefore necessary to make a preliminary test with the solution of stain used and a portion of the tissue. Stain slightly more darkly if the preparation is to be kept for a long period, as most stains, particularly the aniline dyes, fade on exposure to light. After staining, sections must be thoroughly washed with water if an aqueous stain has been used, or with dilute alcohol if an alcoholic stain has been used, in order to remove all traces of the excess stain.

When the sections to be stained are small or fragile, they should be kept in one watch-glass throughout and the reagents, with which they are to be treated, changed with a fine pipette. When a succession of large sections is to be stained, it is more economical to pour out the stains and reagents into separate watch-glasses and transfer the sections by means of a small brush, section lifter, needle, or forceps.

Place the watch-glasses on a sheet of white paper and arrange them in the order in which the reagents they contain are to be used.

CLEARING

The action of a clearing agent (xylol, oil of cloves, or cedar-wood oil [1]) is to render opaque tissues transparent. Clearing is the last stage in the treatment of a section before mounting. Before immersion in a clearing agent and mounting in Canada balsam to make a permanent preparation, all tissues must be thoroughly dehydrated. This is done gradually, to avoid structures collapsing, by immersion in successively stronger solutions of alcohol and water. The final stage of the dehydration takes place by immersion in absolute alcohol. The watch-glass containing absolute alcohol should always be kept covered with another watch-glass or Petri dish. If a milky precipitate is produced when the section is transferred to the clearing agent it should be returned to the absolute alcohol for complete dehydration. A good preparation must contain no cloudiness whatever due to water; this can be easily avoided by allowing plenty of time for the last stage of dehydration with absolute alcohol. The dehydration method provides the most permanent preparation, since water is the main factor in the decomposition of organic matter.

---

[1] Not the same as is used for oil immersion magnification.

Mounting

Objects of high refractive index should always be mounted in glycerine; they need not then first be dehydrated. Glycerine also provides a good fluid for temporary mounts. One drop of pure glycerine is placed in the middle of a microscope slide and the object immersed in it. A coverslip is then lowered on to the drop by hingeing it at one side on the slide and lowering the other slowly with the point of a needle. Sufficient glycerine should be used just to spread out to the edges of the coverslip. The preparation is rendered permanent by painting round the edges of the coverslip with a solution of gold size in xylol; as the xylol evaporates the gold size hardens.

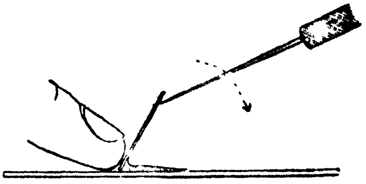

Fig 9. Method of lowering coverslip

A more satisfactory and permanent mounting fluid for most purposes is a syrupy solution of Canada balsam in benzene, xylol, or chloroform. The thoroughly dehydrated section is transferred to a drop of Canada balsam on a microscope slide and a coverslip lowered as before. No gold size is required since the Canada balsam gradually sets and hardens as the solvent evaporates at the room temperature. The process may be accelerated by placing the preparation in an oven which should not be raised above 60° C.

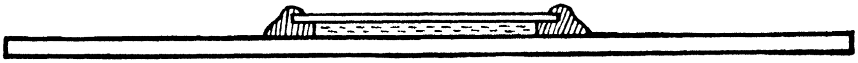

Fig. 10 Side view of framed preparation

When thick tissues are mounted, the coverslip should be supported on thin pieces of glass (broken-up coverslips), or on a frame [1] of Canada balsam which has previously been painted on the microscope slide and allowed to harden. When framed the preparation may be neatly finished off by painting round the edges of the coverslip with Brunswick black dissolved in turpentine.

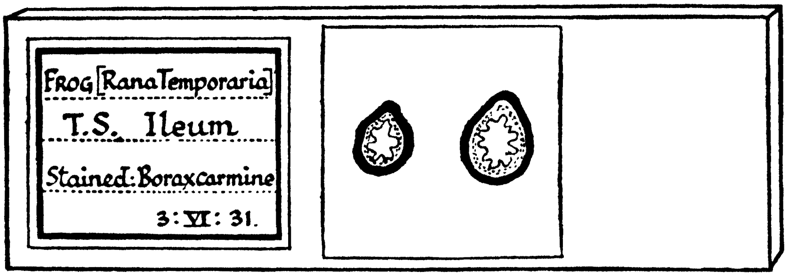

Fig. 11. Microscope slide, prepared and labelled

Coverslips and microscope slides must be kept scrupulously clean. They may be washed with xylol, benzene, or a solution of equal parts alcohol and ether. Keep several microscope slides and coverslips always immersed in alcohol (methylated spirit). When required for use, remove and dry them with blotting-paper and finish off with a fine linen cloth. The test for cleanliness is that a drop of water placed on the glass should spread out evenly. Old preparations may be dismounted by heating gently over the flame of a spirit-lamp in order to melt the Canada balsam and then leaving to soak in xylol.

---

[1] The commercial product 'Brushing Belco' is an admirable substance for making a frame and may also be used for painting round the coverslip to finish off.

STAINS FOR ZOOLOGICAL WORK

The three main types of stains used for biological work are the **Carmines**, the **Haematoxylins**, and the **Anilines**.

Stain	*Solvent*	*Main Use and Reaction*
Borax carmine	50% alcohol	Stains nucleus pink. Acid alcohol (100 c.c. 70% alcohol + 2 drops nitric acid) quickly removes surplus stain. A stain of general utility
Eosin (acid aniline dye)	Alcohol	Stains cytoplasm, used as a counter stain to borax carmine
Haematoxylin	25% alcohol	Stains nucleus blue Sections should be washed with acid alcohol to remove surplus stain
Methylene blue (basic aniline dye)	Water or alcohol	Very dilute solutions can be used to stain nucleus of living organisms
Picro-carmine	Water	Stains nucleus pink. 0·5% hydrochloric acid in water removes surplus stain

METHOD OF STAINING ANIMAL TISSUE

Example.

Section of lining of frog's stomach lying in 50 per cent alcohol in watch-glass.

1. Stain section in borax carmine. 10–20 min.
2. Drain stain away and wash section with 70 per cent alcohol.
3. Add 70 per cent acid alcohol and leave until section turns pink.
4. Add successively 90 per cent alcohol and absolute alcohol. Leave from 5 to 10 min. in each. Keep watch-glass covered with Petri dish whilst lying in absolute alcohol.
5. Place in oil of cloves or cedar-wood oil until clear.
6. Mount in Canada balsam.
7. Cover and label.

After No. 3 the section may be mounted in glycerine by washing with 70 per cent alcohol, placing section for a few minutes in dilute glycerine, and then transferring to a drop of pure glycerine on microscope slide. Cover and seal round edges with gold size.

STAINS FOR BOTANICAL WORK

Stain	*Solvent*	*Main Use and Reaction*
Aniline (hydro)chloride and sulphate	Water	Stains lignin yellow
Bismarck brown (vesuvine)	70% alcohol	Stains cellulose and nucleus brown
Cyanin	Alcohol	Stains lignin blue
Delafield's haematoxylin	Dilute alcohol	Stains cellulose and chromatin purple. Good for general purposes
Iodine	Potassium iodide aqueous solution	Stains starch blue, cellulose yellow, protoplasm brown
Safranin	Alcohol or water	Stains lignin, cutin, and chromatin red
Schultze's solution (chlor-zinc-iodine)	Iodine in aqueous zinc chloride	Stains cellulose pale blue, lignin yellow, cutin brown or yellow. Good for general purposes

METHOD OF SINGLE STAINING OF PLANT TISSUE WITH DELAFIELD'S HAEMATOXYLIN

Example.

Yeast cells lying in watch-glass in 30 per cent alcohol.

1. Stain in Delafield's haematoxylin. 5 min.
2. Wash with tap water.
3. 50 per cent alcohol. 1 min.
4. 70 per cent acid alcohol. 3 min. (This removes any precipitate formed during 2 and 3, and removes stain from cytoplasm, leaving nucleus stained.)
5. 70 per cent alcohol. Leave here until purple colour returns.
6. 90 per cent alcohol. 3 min.
7. Absolute alcohol. 5 min.
8. Oil of cloves or xylol until clear.
9. Mount in Canada balsam.
10. Cover and label.

METHOD OF DOUBLE STAINING OF VASCULAR TISSUE

Example.

Transverse sections from stem of lime lying in watch-glass in 50 per cent alcohol.

1. Stain with safranin. 1–2 hours. If possible allow to stain for full 24 hours by leaving in stain overnight.
2. Wash with 50 per cent alcohol. (This washes out the safranin from the cellulose and leaves the lignin bright red.)
3. Wash with tap water.
4. Stain with Delafield's haematoxylin. 3–30 min. (This stains cellulose blue but has no effect on the lignin.)

5. Wash with tap water.
6. Wash with slightly acidulated water. (This washes away any precipitate caused through using Delafield's haematoxylin.)
7. 50 per cent alcohol. 1 min.
8. 90 per cent alcohol. 1 min.
9. Absolute alcohol. 5 min.
10. Oil of cloves until clear.
11. Mount in Canada balsam.
12. Cover and label.

Another suitable combination: cyanin, 10–20 min. (lignin blue). Wash in water and follow with Bismarck brown, 15–20 min. (cellulose brown). Wash in water again and proceed as from No. 7 above.

METHOD OF MOUNTING IN GLYCERINE

A filamentous alga such as *Spirogyra*, which does not require any stain to show its main structures and will retain its green colour without fixing, may be permanently mounted as follows: Place alga in 10 per cent glycerine in watch-glass and allow water to evaporate; the process may be accelerated by heating in oven to 30° C. When the solution has thickened almost to strength of pure glycerine, transfer alga to drop of pure glycerine on microscope slide. Cover and seal round with Canada balsam or gold size.

STAINS FOR BACTERIOLOGICAL WORK

Bismarck brown.
Fuchsin (carbol fuchsin is often more effective since phenol, 'carbolic acid', acts as a mordant).
Gentian violet.
Methylene blue (carbol methylene blue is sometimes more effective).

In every case a saturated solution is made in alcohol and then watered down with distilled water.

All these are basic aniline dyes which are nuclear stains and therefore stain the whole of the bacteria. When bacteria in a tissue are mounted *in situ*, the preparation is usually stained with eosin, an acid aniline dye, which stains the cytoplasm of the surrounding material in contrast to the nucleoplasm of the bacteria, which remains unstained.

METHOD OF STAINING AND MOUNTING A FILM PREPARATION

1. Smear over *clean* coverslip a sample of culture of bacteria with previously sterilized platinum loop.
2. Hold between finger and thumb and pass through small flame[1] with bacteria film uppermost. (This kills and fixes the bacteria.)

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[1] A spirit lamp is better than a Bunsen burner.

3. Stain, either by immersing whole coverslip in watch-glass containing the selected stain, or running stain on to film on coverslip with a fine pipette. (Time taken entirely depends on strength of stain. Heating, by holding coverslip over flame for a second, accelerates process.)
4. Wash in tap water.
5. Dry by exposure to air and laying between blotting-paper.
6. Mount by inversion of coverslip over drop of Canada balsam, dissolved in xylol, placed on microscope slide.
7. Label.

DISSECTIONS

The object of a dissection is to reveal as clearly as possible the arrangement of the organs under review. Small animals are dissected under water, as this supports the dissected tissues (and reduces the smell). The pins or nails holding the animal to the bottom of the dissecting dish or board should be continually moved in order to keep the organs stretched and taut. The dissection should be open and clear and a tangled, complicated mass of organs always straightened out.

If it is desired to reveal the details of only one structure, for example the generative organs of a frog, the alimentary canal and other unconnected structures should be removed. This leaves the required parts clearly revealed and lying *in situ* in the body of the animal. Always keep a dissection tidied up by removing all ragged ends of skin or body wall and any tissue which has been cut out. When dissecting under water, change the water continually and dissect along, not across, such structures as nerves and blood-vessels. Vertebrates are dissected from the ventral and invertebrates from the dorsal side.

After studying the external characters and inside of the mouth, the usual order of dissection of a vertebrate is as follows:

1. Peel off skin to reveal muscular body wall.
2. Open body wall from ventral side, and note general arrangement of organs as they lie *in situ*.
3. Dissect out alimentary canal and blood-vessels which serve it.
4. Remove gut. Dissect out vascular system (heart and blood-vessels).
5. Dissect out genital and excretory organs.
6. Dissect out brain and nervous system.

The skeleton may then be prepared, articulated, and studied.

It is essential to keep dissecting instruments sharp and well greased when left for any period. A scalpel and an old pair of scissors should be kept solely for cutting cartilage, bone, and hard integument.

The following are necessary instruments for botanical and zoological work:

Large and small pair of scissors with sharp points.
Large and small pair of forceps.
Two or three scalpels.
Mounted needles and seeker.

A blow-pipe.

A fine pipette.

One or more good razors.

A platinum wire fused into a glass holder for bacteriological work.

A fine linen cloth should be kept for drying and polishing instruments, microscope slides, and coverslips.

A mounted lens on stand or watchmaker's eye-lens which can be used when dissecting, leaving both hands free.

CLASSIFICATION OF PLANTS INCLUDED

THALLOPHYTA (Gk. *thallos*, young shoot; *phyton*, plant). No differentiation into stem, roots, or leaves.

1. **Algae.** *Protococcus*, *Euglena*,[1] *Chlamydomonas*, *Haematococcus*, *Pandorina*, *Volvox*, *Spirogyra*, *Vaucheria*, *Fucus*.

2. **Fungi.** *Mucor*, *Penicillium*, *Pythium*, *Puccinia*, *Peronospora*, *Psalliota* (*Agaricus*), *Saccharomyces*.

3. **Bacteria.**

BRYOPHYTA (Gk. *bryon*, moss; *phyton*). Differentiation into stem and leaves, no true roots, poorly developed or no vascular system.

1. **Hepaticae** (Lat. liverworts). *Pellia*, *Marchantia*.

2. **Musci** (Lat. mosses). *Funaria*.

PTERIDOPHYTA (Gk. *pteris*, fern; *phyton*). Stem, leaves, and developed vascular system.

1. **Filicales** (Lat. ferns). *Nephrodium*, *Pteris*.

2. **Lycopodiales** (Gk. *lukos*, wolf; *pous*, foot). *Selaginella*.

SPERMOPHYTA (Gk. *sperma*, seed; *phyton*).

1. **Gymnospermae** (Gk. *gymnos*, naked; *sperma*). Reproduction by seeds which are exposed and often borne in cones. *Pinus*, *Picea*, *Larix*.

2. **Angiospermae** (Gk. *angeion*, vessel; *sperma*). Seeds enclosed in carpels. True flowering plants which produce fruits.

(A) **Dicotyledones.** *Ranunculaceae*, *Cruciferae*, *Rosaceae*, *Leguminosae*, *Umbelliferae*, *Primulaceae*, *Labiatae*, *Scrophulariaceae*, *Compositae*.

(B) **Monocotyledones.** *Liliaceae*, *Amaryllidaceae*, *Gramineae*.

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[1] *Euglena*, in common with similar motile unicellular forms, is variously classed with plants or animals. Since photosynthesis is its main mode of nutrition, it is here classed for convenience with the plants.

PLANT MORPHOLOGY

THALLOPHYTA (Algae)

Protococcus[1] (Gk. *protos*, first; *kokkos*, grain or berry). Found in masses on the shaded side of the bark of trees where it is less likely to get dried up.

1. Scrape off some of the green mass from the bark into a drop of water on a microscope slide. Spread out with needles and cover with coverslip. Observe under low power the tiny green cells, single and in clusters. Under high power note stages of cell division with incomplete segregation. Focus on one large single cell. NOTE: *cell wall, pyrenoid,* and *chloroplast* which usually masks the nucleus.[2] Irrigate with dilute iodine solution (iodine dissolved in solution of potassium iodide in water); starch stains blue-black, cellulose walls stain light yellow.

2. **Draw** stages of cell division under low power and one cell under high power, filling in all the details you can see.

Euglena (Gk. *eu,* well; *glene,* pupil; hence bright-eyed).

1. Place sample of water containing *Euglena* in watch-glass on stage of microscope and note under low power the light green specks darting in all directions.

2. With a pipette mount a drop of the water on a slide and cover. Flagella get trapped and so arrest the organism. Under low power note changes in shape of the body of organism thus anchored. Fix and stain by irrigation with dilute iodine solution. NOTE under high power: *cell wall, eyespot, contractile vacuole, oval chloroplasts, gullet.* Nucleus stains dark brown with iodine and should be visible. **Draw** one organism under high power and fill in all the details you can see.

Chlamydomonas (Gk. *chlamys,* cloak; *monas,* unit). Observe as for *Euglena* first alive in watch-glass, then mount on slide in drop of water and cover. Fix and stain by irrigation with dilute iodine solution. Under high power NOTE: *cell wall, chloroplast, pyrenoid, eyespot.* **Draw** one cell under high power; try and find stages of cell division.

Haematococcus (Gk. *haima,* blood; *kokkos,* grain or berry). This organism is reddish in appearance owing to the red pigment dissolved in the cytoplasm. The protoplasm containing green *chloroplast, pyrenoid, nucleus,* and two *flagella* is suspended inside the rounded cellulose cell wall by thin protoplasmic strands; these pass through the gelatinous lining of the cell wall. Mount in a drop of water. **Draw** one cell under high power.

Pandorina and **Volvox** (Lat. *volvo,* I roll). Examine a prepared slide of **Pandorina.** NOTE the green specks (*cells*) lying close together in the transparent *coenobium. Pandorina* is a colony of the first order; each cell is independent and is sufficiently generalized to form *gametes* or divide vegetatively to form a new colony.

Volvox may be found in fresh-water ponds.

1. Observe specimens in a drop of water under low power. *Volvox* is a colony of

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[1] Also called *Pleurococcus*.

[2] The nucleus was first discovered in plant cells by the Scottish botanist Robert Brown in 1831.

THALLOPHYTA

the second order; all the cells are connected by protoplasmic strands and cannot exist independently. A few cells are specialized to form male and female *gametes.*

2. Irrigate with iodine solution. *V. aureus* has thin protoplasmic connections. *V. globator* is larger, the cells are closer together in the *coenobium* and the protoplasmic connections are stouter.

3. **Draw** a portion of the *coenobium* under high power, also any developing *parthenogonidia, androgonidia,* and *gynogonidia.*

4. **To make a permanent preparation of Volvox colonies.** Fix in corrosive sublimate and acetic acid mixture and mount in glycerine (page 10). Support the coverslip on pieces of broken glass to prevent crushing the colonies.

Spirogyra (Gk. *speira,* coil; *guros,* ring). Found in masses as tangled threads floating in stagnant fresh-water. Mount a few threads in water, note their sliminess to the touch, and examine under low power.

1. NOTE: transverse *septa,* dividing threads into cells; *vacuoles;* spiral *chloroplasts,* containing highly refractive *pyrenoids.* Stain with iodine solution. **Draw** one cell under high power showing: *nucleus* with *nucleolus;* protoplasmic bridles running to the *pyrenoids* which stain purple; *vacuole.*

2. **Draw** stages of conjugation from prepared slides.

3. **To make a permanent preparation of Spirogyra.** Fix in Flemming's fluid and mount in glycerine (page 10).

Zygnema is frequently found with *Spirogyra* and is very similar, but has two star-shaped chloroplasts in each cell.

Vaucheria (named after the botanist *Vaucher*). Found growing in masses on moist soil and in water. The separate filaments are large enough to see with the naked eye.

1. Examine a portion in water under low power. NOTE: the branching cylindrical tubes; oval *chloroplasts;* refractive *oil globules;* the *nuclei* of this *coenocyte* are too small to be seen. There are no cross cell walls. Both male and female sexual organs are borne on the same branch. Mature *antheridia* are curved bodies containing biciliate sperms, mature *oogonia* are oval bodies containing one uninucleate ovum.

2. **Draw** a portion of the alga, and sexual organs, if present, under low power.

Fucus (Lat. seaweed). *F. serratus,* the sea wrack, common round the coast between tide marks. Distinguished by flat serrated *thallus* and absence of bladders. *F. vesiculosus,* the bladder wrack, also very common, has bladders filled with gas which make it lighter.

1. **Draw** a portion of *F. serratus*: *thallus* divided up into *frond,* with serrated edges, *stipe,* and *holdfast;* swollen branches of the frond containing fertile *conceptacles,* sterile conceptacles appear as dots scattered over other parts of the frond; *midrib;* position of *apical cell.*

2. (*a*) **Draw** from transverse section of frond under hand-lens: conceptacles; regions of *medulla, cortex,* and *palisade cells.*

(*b*) **Draw** under low power: male conceptacle, showing *sterile filaments, antheridia,* isolated *antheridia* liberating *spermatozoids;* female conceptacle, showing *sterile filaments,* developing *oogonia, ova.* In *F. serratus* the male and female conceptacles are borne on separate plants, the former appear as little red spots. If possible **draw** fresh *ova* and *spermatozoids* mounted in sea-water, with *nucleus, phaeoplast,* and *cilia,* under high power.

(*c*) **Draw** from transverse section of frond under high power: *palisade* cells with *phaeoplasts*; *cortex cells* with *phaeoplasts*; *medulla* containing *mucilage,* primary *medullary filaments,* thick-walled *hyphae* which have grown out from the cortical cells.

3. **Draw** a longitudinal section through a developing frond showing *apical cell* and developing tissues.

THALLOPHYTA (Fungi)

The common saprophytic moulds can be grown at room temperature on bread pulp. This may be prepared by powdering up dry white bread, mixing with enough water to form a thick pulp, and finally sterilizing with the containing vessel in an autoclave or steam oven.

Mucor (Lat. mouldiness). Common white mould with the appearance of cotton-wool.

1. Examine with a hand-lens a portion of the *mycelium* growing on the bread medium and note the black specks (*sporangia*) growing on the ends of aerial shoots. Remove some of the mycelium, soak for a minute in dilute alcohol, and mount in dilute glycerine on a microscope slide.

2. (*a*) **Draw** under low power: *hyphae, sporangia, spores, columella* in burst sporangium.

(*b*) **Draw** under high power: *hypha,* showing *vacuoles.* NOTE absence of cross cell walls (*non-septate*).

3. **Draw** from prepared slides stages in formation and germination of *zygotes.*

Penicillium (Lat. brush). Common blue mould growing on many brands of cheese.

1. Examine as for *Mucor.*

2. (*a*) **Draw** under low power: *hyphae*; *conidiophores,* with *conidia* radiating out like the bristles of a brush but branched.

(*b*) **Draw** under high power: *hypha* with blue-green *cytoplasm* and transverse cell walls (*septate*).

Aspergillus is a similar fungus to *Penicillium.* The mycelium changes colour from white through blue to yellow. The *conidiophores* have rounded tops from which chains of *conidia* project in all directions. The yellow colour is due to the formation of *perithecia* which represent a degenerate mode of sexual reproduction.

Pythium (Gk. *pythein,* to rot). Cress seedlings sown thickly and frequently watered often become infected with this *facultative parasite.*

1. Examine some of the *mycelium* of *Pythium* by removing it from the seedlings and mounting in a drop of water on a microscope slide. **Draw** under low power: *hyphae* (*non-septate*), *conidia.* If the soil is very wet, *zoosporangia,* containing *zoospores,* may be present. The former have grown out from conidia.

2. **Draw** from prepared slides: developing *antheridia* and *oogonia*; mature *oogonia* containing fertilized *zygotes* (*oospores*).

Puccinia (named after *Puccini,* an Italian anatomist). The *obligate parasite* known

THALLOPHYTA

as rust, found on the stems and leaves of wheat, the alternate phase occurring on the common barberry.

1. Examine stems and leaves of wheat infected with this parasite. NOTE the longitudinal slits filled with dark-coloured masses of spores.

2. **Draw** from prepared slides: *mycelium* within the tissues of the wheat; one-celled *uredospores*; *teleutospores* made up of *exospore* and *endospore*; *aecidium cups* on the leaf of the barberry (*Berberis vulgaris*); septate *mycelium* ramifying into the intercellular spaces; *hymenium*; *aecidiospores* in chains; *peridium*.

Peronospora (Gk. *perone*, pin; *sporos*, seed). An *obligate parasite* found on Cruciferae. The mycelium does not break through the tissues of the host to the outside. Conidiophores are produced at the ends of hyphae which grow out through the stomata of the leaves.

1. Examine leaves of infected plant and NOTE branched *conidiophores* and *conidia*.

2. **Draw** from prepared slides: *hyphae* ramifying between the cells of the host; *haustoria*, containing dense protoplasm, *within* the cells; any stages in the process of sexual reproduction, which takes place within the tissues of the host; club-shaped *antheridium*; *oogonium*; *oospore*.

If available the following should also be examined: *Phytophthora* (Gk. *phyton*, plant; *phthoros*, destroying), the potato blight. Examine the under surface of the leaves of the potato plant and note the *conidiophores*. *Saprolegnia* (Gk. *sapros*, rotten; *legnon*, edge), the facultative parasite which attacks organic material (dead flies, etc.) in fresh-water. NOTE: *hyphae*; *sporangia*; *zoospores*.

Psalliota (Agaricus) campestris. This is the common edible mushroom and may be recognized by the following characteristics. In the 'button' stages the fungus is whitish and nearly round. In the maturing mushroom the *pileus* is first hemispherical and then nearly flat and the 'skin' peels easily; in cultivated forms the 'skin' is more scaly. The *gills* are thin, crowded together, at first whitish and then turn through pink to dark brown. The *stipe* has a 'collar' (*annulus*). *Psalliota xanthoderma* is a poisonous[1] form which is very similar to the edible mushroom. As its specific name implies, it has a skin which turns yellow when cut and it also possesses an unpleasant smell.

1. (*a*) Examine some mushroom 'spawn' (*mycelium*). **Draw**: developing fructifications.

(*b*) Place some of the mycelium in a drop of water on a microscope slide. **Draw** under high power: the branching *hyphae* with *septa*.

2. Cut through young and mature fructifications longitudinally. **Draw**: *pileus*; *gills*, note that they are free and not attached to the *stipe*; *annulus*.

3. Remove a portion of the lower surface of a gill, mount in a drop of water. **Draw** under high power: *hymenial* layer made up of *basidia* and *basidiospores* (two to four are borne on each basidium).

4. Carefully remove the complete pileus from a mature mushroom and place, gills downwards, on a sheet of white paper. Remove after leaving for several hours.

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[1] Further details on poisonous and non-poisonous fungi may be obtained from Bulletin No. 23, *Edible and Poisonous Fungi*, published by the Ministry of Agriculture and Fisheries.

NOTE the radiating dark streaks due to the spores which have fallen off and mark the arrangement of the gills.

5. Transverse sections of the stipe may be cut and examined under low power after mounting in glycerine. NOTE the interwoven *hyphae* which lie closer together on the outside. **Draw** under high power: *hyphae* with branches; *septa*; *intercellular spaces*.

Yeast, Saccharomyces (Gk. *sakchar*, sugar; *mykes*, fungus). Brewers' yeast is obtained as a creamy froth and consists of numerous chains of cells. Bakers' yeast is obtained as a putty-like substance in which the cells are single or have formed short chains.

1. **To show the anaërobic fermentation of yeast.** Make a solution of cane sugar or glucose [1] in water and place in a flask with some yeast cells. Pasteur's culture solution (page 132) may be used as an alternative. Stopper the flask with a cork through which runs a delivery-tube. Allow the other end of the delivery-tube to dip into lime-water contained in a flask, the cork of which is fitted with an open tube containing caustic potash to prevent ingress of carbon dioxide from the air (Fig. 12). As the fermentation proceeds, a froth is formed on top of the sugar solution, and carbon dioxide gas passes along the delivery-tube and precipitates calcium carbonate from the lime-water:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} = \underset{\text{(ethyl alcohol)}}{2C_2H_5OH} + \underset{\text{(carbon dioxide)}}{2CO_2\uparrow}$$

Allow the apparatus to stand at room temperature for several days. When the froth has disappeared from the culture solution, alcohol may be distilled off.

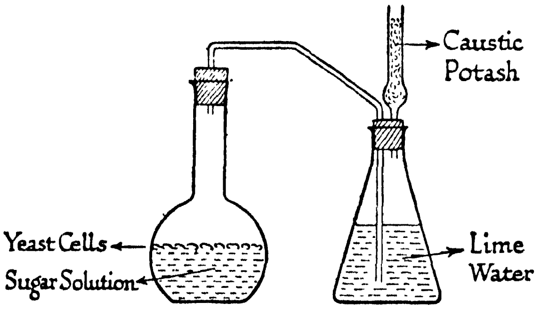

Fig. 12. The fermentation of yeast

2. Place some yeast on a microscope slide, add a drop of iodine solution, cover, and examine under high power. **Draw**: stages of *budding*. NOTE the orange-red stain due to *glycogen* in the yeast cells.

3. Stain a sample of yeast, using the method for staining and mounting a film preparation described on page 9. Methylene blue, gentian violet, or any other basic aniline dye may be used. **Draw** under high power: cells showing *cell wall, cytoplasm, intra-nuclear vacuole.*

BACTERIA

Cultures of bacteria may be obtained from the National Collection of Type Cultures, Lister Institute, Chelsea Bridge Road, London, S.W.3. The following are suitable for study: *Bacillus aceti, B. acidi-lactici, B. phosphorescens, Streptococcus acidi-lactici, Clostridium butyricum, Sarcina lutea, Chromobacterium violaceum.*

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[1] Yeast cells contain, *inter alia*, the enzymes zymase and invertase.

BACTERIA

PLANT MORPHOLOGY

1. Pour some warm water on a handful of hay, filter the mixture through filter-paper. Allow the filtrate to stand covered over in a beaker for several days. Samples of *Bacillus, Spirillum,* and *Coccus* forms may sometimes be found in the liquid. If the water be *boiled* only spores of *Bacillus subtilis* will survive.

2. Make preparations of bacteria using the method for staining and mounting a film preparation described on page 10. Use any of the basic aniline dye stains. Examine the preparations under oil immersion magnification (page 1), and **draw** any of the distinctive shapes you can see. NOTE that all of the protoplasm of bacteria stains equally.

3. (*a*) Melt some agar jelly or gelatine by placing in a vessel surrounded by boiling water. When melted pour the jelly into previously sterilized test-tubes and Petri dishes.[1] Plug the former with cotton-wool and cover the latter. Expose the agar jelly in a Petri dish to the air in a room for half an hour. Cover, incubate at 37° C. if possible, and leave for a week, then examine for any cultures of bacteria.

(*b*) Inoculate the agar jelly in the test-tubes with various samples of bacteria, using a platinum wire which is sterilized before and after use by heating in a small flame. Plug the test-tubes with cotton-wool, leave for a week, and then examine the new cultures.

4. Boil some of the hay decoction, then filter into a sterilized test-tube, plug the mouth with cotton-wool, and leave until a scum forms on the surface of the liquid. Withdraw a sample of the liquid with a pipette, and NOTE under high power the *ciliated bacilli*. Treat a sample of the scum in the same way and NOTE the cells aggregated together in long filaments and embedded in a mucilaginous substance (*zooglea stage*). Spores may also be present.

From demonstration slides **draw** the following: *B. anthracis* (look for spore formation); *B. typhosus*; *B. tuberculosis*; *B. coli*; *B. radicicola* in nodules on roots of Leguminosae.

BRYOPHYTA (Hepaticae)

Liverworts may be found growing in abundance on the banks of fresh-water streams and in damp, shady places.

Pellia. Examine a single plant under a hand-lens.

1. (*a*) **Draw**: *thallus*, mark position of apical cell; *midrib*; *antheridia* and *archegonia*, which are borne on the top surface of the thallus, the latter at the ends and protected by the *involucre*; *sporogonia* in various stages of development.

(*b*) Dissect out a mature sporogonium and **draw** *capsule, stalk,* and *foot.*

2. (*a*) **Draw** from prepared slide of longitudinal section through thallus: *archegonia*; *involucre*; *antheridia*; *rhizoids* attached to under surface; *cells* containing *chloroplasts* and *starch grains*. NOTE the absence of air-spaces and lack of any differentiation of the cells. The thallus is *monoecious*.

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[1] Do this through a previously sterilized funnel in order to prevent the agar jelly adhering to the mouth of the test-tube and sticking to the plug of cotton-wool.

(*b*) **Draw** the reproductive bodies under high power:
antheridium, showing outer wall made up of cells, developing male gametes;
archegonium, showing *neck* and *venter* containing egg cell.

3. **Draw** an opened spore capsule with its four flaps, as seen under high power: *elaters*; multinuclear *spores*, containing *chloroplasts*.

Marchantia (named after *Marchant*, a French botanist). The common *M. polymorpha* has a larger thallus than *Pellia* and is divided into rhomboidal areas on the top surface with an opening in the centre of each. These are the openings to the internal assimilating chambers. Rhizoids and violet or brown coloured scales consisting of a single layer of cells grow on the under surface. The thallus has a distinct midrib and bears little green buds (*gemmae*) in cups which when detached grow into new thalli. The thalli bear either male or female organs (*dioecious*). A mature *antheridium* consists of an oval capsule, the wall of which is made up of a single layer of cells containing chloroplasts. Inside are biciliate sperms. The capsules are borne on the end of a thin multicellular stalk and form the *antheridophore*. The *archegonia*, consisting of neck and venter with oosphere, are arranged radially on the under surface of a star-shaped receptacle. The archegonia are enveloped by a curtain-like membrane. The receptacle, with the archegonia, is borne on a stalk and forms the *archegoniophore*. Sporogonia are produced as in *Pellia*.

1. **Draw** the top surface of thallus showing: *pores*; circular cups bearing *gemmae*; any of the reproductive bodies. Wash the under surface carefully and **draw** *midrib* and *rhizoids*.

2. **Draw** under high power, from prepared slide of transverse section through thallus: *assimilating chamber* with *pore* and cells containing *chloroplasts*. NOTE absence of air-spaces and lack of differentiation of cells of the thallus.

3. Sections may be cut across the thallus of *Pellia* or *Marchantia*. When cut from fresh material, mount in glycerine and NOTE cells containing chlorophyll. Mount other sections in Schultze's solution. The thalli may be hardened by immersion in 50 per cent alcohol if necessary.

BRYOPHYTA (Musci)

Funaria (Lat. *funarius*, rope-like). A widely distributed moss found on walls and dry barren places, especially where a wood fire has been burnt.

1. (*a*) Isolate from a tuft of moss a single plant and examine with a hand-lens. **Draw** the whole plant: *stem*; *leaves*; *rhizoids*; *sporogonium*, if present; *antheridia* borne at the apices of the stem and surrounded by foliage leaves; *archegonia* borne on other branches lower down on the same stem.

(*b*) Mount a single leaf in water and NOTE under high power the midrib and cells containing chlorophyll.

2. From prepared slides make drawings of the following structures:

(*a*) Transverse section of leaf; *blade* made up of single layer of thick-walled cells, *midrib* composed of thin-walled conducting cells.

(*b*) Transverse section of stem; outer cortex composed of thick-walled cells containing

BRYOPHYTA

chlorophyll, middle cortex with thin-walled parenchymatous cells, and thin-walled conducting cells in the centre.

(*c*) Longitudinal section through ***antheridia,*** surrounded by wall of cells and containing developing male gametes, also adjacent club-shaped sterile filaments containing chloroplasts (*paraphyses*).

(*d*) Longitudinal section through ***archegonia,*** composed of ***neck,*** and ***venter*** containing egg cell.

(*e*) Longitudinal section through *sporogonium*; *lid*; two rows of ***peristome teeth,*** assimilating tissue with *stomata* and air-spaces, spore-producing tissue and developing spores.

(*f*) *Protonema* with cell walls, colourless rhizoids, branching filament with chlorophyll and buds.

3. Sections may be cut across the stem of *Funaria,* which should be held in pith, and also across the sporogonium. Mount in dilute glycerine.

From a consideration of these examples of the Bryophytes, it can be seen that the sexual generation (*haploid gametophyte*) is more highly developed vegetatively than the non-sexual generation (*diploid sporophyte*).

PTERIDOPHYTA (Filicales)

Nephrodium[1] (Gk. *nephros,* kidney). This is the common male-fern and the best known of our native species. The name is an allusion to the shape of the ***indusia.*** The root stock is large, due to the accumulated bases of old leaves; the active ***rhizome*** is small and runs through the centre.

1. NOTE the straight erect *rachis,* covered with brown scaly hairs and bearing lance-shaped *frond.* The stalks of the ***pinnae*** are straight, unbranched, and support the ***pinnules*** in two lateral rows. The pinnae and pinnules are both arranged alternately. The 'fern-plant' is the non-sexual generation (*diploid sporophyte*) and bears spores in July or August.

2. **Draw** by observation with naked eye a single fertile ***pinna*** from the under side: ***pinnules,*** more distinct towards the base of the pinna; kidney-shaped ***indusia*** covering the *sporangia,* which grow in small groups called *sori.* Put in the ***veins*** and NOTE that the sori are arranged on each side of, and parallel with, the ***midrib*** of the pinnule.

3. Prepare transverse sections of sori by cutting fertile pinnules in the region of the sporangia. Mount in dilute glycerine. From these preparations, or from prepared slides, **draw** under low power a single sorus: ***indusium*** mounted on ***vein***; ***sporangium*** made up of *stalk,* and *capsule* with *annulus.* NOTE any ruptured sporangia and examine any freed spores under high power. All the spores are alike (***homosporous***).

The sexual generation (*haploid gametophyte*) is called the ***prothallus.*** These will sometimes grow from spores when sown on damp soil and kept in a damp, humid atmosphere. They are frequently found in late summer growing on the sides of flower-pots in greenhouses containing ferns. If available, make a permanent preparation of whole prothallus in glycerine (page 10). Examine your preparation, or a prepared slide of a prothallus for the following work.

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[1] Also called *Aspidium* and *Dryopteris.*

4. (*a*) **Draw** the outline of whole prothallus from the under surface, using a hand-lens: *rhizoids*; position of *antheridia* and *archegonia*; developing *sporophyte* if present. NOTE the presence of chlorophyll in the cells of the thallus.

(*b*) **Draw** under low power: *antheridium*, rounded outgrowth containing developing male gametes with outer wall of cells; *archegonium* with *neck*, and *venter* containing egg cell. NOTE the actively growing cells in the region of the apex.

Pteris[1] (Gk. fern). This is the ubiquitous bracken or brake-fern. It has a perennial underground stem (rhizome) covered with fine brown hairs and sending roots in all directions. Each year the rhizome sends up a single erect and unbranched stem bearing the frond.

1. Examine the frond of a mature bracken plant. NOTE that the *pinnae* are arranged oppositely on the stem whilst the arrangement of the *pinnules* is alternate. The frond is thrice pinnate. The *sporangia* occur in lines along the edge of the under side of the pinnules. The *indusium* is continuous with the edge of the pinnules.

2. Cut transverse sections across the rhizome of *Pteris*. Mount some sections in Schultze's solution, stain others in Delafield's haematoxylin, and mount in Canada balsam (page 9). From your sections, **draw** the general arrangement of the tissues as seen under low power: protective tissue with thick cell walls (*sclerenchyma*) round the outside; an incomplete ring of sclerenchyma in the centre; groups of conductive tissue and isolated fibres of sclerenchyma in ground cells of *parenchymatous* tissue containing starch grains. (The structure of conductive tissue is considered in the section on Angiosperms.) Amongst the Pteridophytes the non-sexual generation is well developed and perennial, whilst the sexual generation is much smaller and leads a transitory existence.

PTERIDOPHYTA (Lycopodiales)

Selaginella (Lat. dim. of *selago*, club-moss). *S. Kraussiana*, the best known species, is grown in greenhouses and resembles a large branching moss. The plant is the sporophyte and is covered with small leaves of two sizes. The only British species, *S. spinosa*, found in mountain districts, is much smaller and has all its leaves alike.

1. Examine plant with naked eye. **Draw**: *stem* with four rows of *leaves*, two rows of small leaves on upper surface, two rows of larger ventral leaves at the sides; branches which grow from lateral buds but are not axillary, and lie in one plane; white *rhizophores* which are developed exogenously at the points where the stem branches and give rise to true *roots* on reaching the soil. NOTE that each leaf has a *midrib* and a small scale (*ligule*) on the base of its upper surface.

2. On short erect branches of the stem (*cones*) look for the *sporangia*; these are borne singly in the axils of leaves which are all alike.

NOTE: *Megasporangia*, green or brown in colour, tetrahedral shape, found in axils of lower leaves and each containing four *megaspores*.

Microsporangia, reddish-brown in colour, spherical shape, found in axils of upper leaves and containing many *microspores*.

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[1] Also called *Pteridium*.

PTERIDOPHYTA

In mature cones the sporangia may have opened.

3. **Draw** plan of transverse section of stem from prepared slide: *epidermis*; *cortex*; *air-spaces*; *endodermis*; *pericycle*; *phloem*; *xylem* and *protoxylem.*

4. **Draw** from prepared slide of longitudinal section of stem: *megasporangium* with *megaspores*; *microsporangium* with *microspores*; *leaves* with *ligules*; *stem* with *endodermis* and *vascular bundle.*

5. **Draw** from prepared slide of longitudinal section through female prothallus: *coat* of spore; *cells* of prothallus; *rhizoids*; developing *embryo* with *foot*, *suspensor*, developing leaves (*cotyledons*) and *stem*; unfertilized *archegonium* with *neck* and *oospore.*

6. **Draw** from prepared slide of developing male prothallus: *prothallus cell*; *central cells* breaking up into biciliate sperm cells; *peripheral cells* forming wall of the antheridium.

7. **Draw** from prepared slide of developing sporophyte attached to megaspore: *coat* of spore; *food reserve*; abortive *archegonia*; *foot*; *cotyledons* with *ligules*; *stem.*

SPERMOPHYTA (Gymnospermae)

Pinus.

1. Examine a branch stem of *P. sylvestris*, the Scots pine. The branch must be at least three years old. The most recent year's growth may be seen in the amount of stem from the apical bud to the first whorl of scale leaves. The increments of growth of former years can be distinguished by the successive stages of thickening and darkening of the axis. The scale leaves on the older parts of the stem are harder and show the scars of former dwarf shoots. NOTE: *apical bud* covered with *scale leaves*; one or more *lateral buds* also covered with *scale leaves.* These buds are capable of growing out into branches.

2. The leaves (pine-needles) are borne in pairs, arranged spirally round the stem, and grow on dwarf shoots in the axils of scale leaves. They are found on the tree all the year round (*evergreen*). Remove pair of foliage leaves and scale leaf. Cut longitudinally *through* the leaves at the base. **Draw** under hand-lens: *foliage leaves*; *stem apex* of *dwarf shoot*; sheathing *scale leaves*; larger *scale leaf* in the axil of which the shoot has grown.

3. The male and female cones are borne at the apices of different stems on the same tree (*monoecious*). The female cone takes three years to develop. It is produced from a lateral-bud near the apex, and is made up of spirally arranged scales.

(*a*) NOTE: **first-year female cone** in early summer, borne at apex on *stalk* which bends down, covered with *ovuliferous scales* arranged spirally, single scale with two *ovules* and wide *micropyles*;

second-year female cone, borne at base of first increment of growth passing from apex, resembles first-year cone though larger;

third-year female cone, borne at base of next successive increment of growth passing from the apex, *ovuliferous scales* are brown and are beginning to separate.

Remove the ovuliferous scale from a third-year cone. **Draw**: *ovuliferous scale*;

smaller *bract scale.* NOTE the two *seeds* which lie at the base of the ovuliferous scale and on its upper surface. The wide *micropyles* are directed towards the base of the scale.

(*b*) NOTE: **male cone,** which is also produced from a lateral bud at the apex of a stem, made up of *stamens,* each a scale with two *pollen sacs* below, arranged spirally round central axis. Cut longitudinal section through a male cone, mount in dilute glycerine. **Draw** under low power: *axis*; *stamens*; *pollen sacs.*

4. Under low power, observe a transverse section from the stem of *Pinus* and NOTE the *resin passages.* The seedling of *Pinus* has several cotyledons.

5. (*a*) Examine a branch stem of *Picea,* the spruce. NOTE: terminal and lateral buds; needle leaves borne singly; female cones which hang down and have thin scales.

(*b*) Pull off a few foliage leaves and observe that they do not leave a small scar since their attachment extends downwards along the stem (*decurrent*). The spruce is an evergreen and the seedlings have several cotyledons.

6. Examine a branch stem of *Larix,* the larch, in early summer. NOTE: small, soft, light-green needle leaves borne in clusters; short shoots; female cones with thin ovuliferous scales and borne upright on the stem. The larch is deciduous and the seedlings have several cotyledons.

7. Make a sketch of the stems and leaves of *Picea* and *Larix.*

SPERMOPHYTA (Angiospermae)

HERBS

1. **Annuals.** Groundsel (*Senecio vulgaris*) may be found all the year round since many generations follow one another successively during the summer, and the seeds which are produced in the autumn germinate and spend the winter as seedlings. **Draw** a portion of the stem showing: *nodes*; *internodes*; *axillary buds*; *terminal buds*; *flower buds.* NOTE the *alternate* arrangement of the leaves and that growth is *sympodial.* **Draw** samples of the various kinds of leaves: those near the ground with *petiole* (*petiolate*), *blade,* and *midrib*; those farther up the stem which are *sessile,* having no petiole. Wash the roots carefully and **draw**: main *taproot* and *branch roots.*

2. **Perennials.**

(*a*) **Rhizomes** (underground stems). **Draw** rhizome of Solomon's seal (*Polygonatum multiflorum*): fleshy *rhizome*; *scars* of former aerial shoots; *scale leaves* covering *terminal bud*; *circular scars* of old scale leaves; *adventitious roots.* NOTE that the growth of the rhizome is *sympodial.* Compare rhizomes of iris; wood anemone (*Anemone nemorosa*); couch grass (*Triticum repens*).

(*b*) **Root-Stocks** (underground root+stem). **Draw** root-stock of primrose (*Primula vulgaris*): rosette of *foliage leaves* above ground level; *bases* of old leaves; *adventitious roots.*

(*c*) **Storage Roots.** **Draw** storage roots of lesser celandine in early summer: tuberous

SPERMOPHYTA

adventitious roots growing in leaf axils. Compare fibrous *root-tubers* of the dahlia, autumn stage.

(*d*) **Tubers** (portion of underground stem). **Draw** potato tuber: remnant of stem; spirally arranged *scale leaves*, three buds in the axil of each (*eyes*); *terminal eye*. Examine a sprouting potato, growth will probably have started from several buds. Compare tuber of Jerusalem artichoke (*Helianthus tuberosus*).

(*e*) **Corms** (base of stem). Examine a crocus corm in the resting stage. Pull off the dried *scale leaves*. **Draw**: circular *scars* left by the scale leaves; *axillary buds*; scar or remnant of stem at apex of corm; *scar* at the base where it was attached to the previous year's corm; rudiments of fibrous roots. Cut through the corm, passing through stem remnant and an axillary bud, add a drop of iodine solution to the cut surface. NOTE *vascular channels* and distribution of starch. Examine a chain of montbretia corms. NOTE: *adventitious roots*; *contractile roots*; *creeping stems* which may terminate in small corms.

(*f*) **Bulbs** (storage food leaves). Cut longitudinally through the middle of tulip bulb. **Draw**: dry protective outer *scales*; fleshy *bulb scales* which are complete; *terminal bud* developing into aerial stem, flower, and leaves; *axillary buds*; basal *stem* with *scar* of attachment to previous year's bulb; rudiments of fibrous roots. Compare bulb of the daffodil: the bulb scales are the swollen bases of foliage leaves and the aerial shoot grows from an axillary bud.

3. **Biennials.** **Draw** carrot at end of first year's growth: swollen *taproot*; *branch roots*; *foliage leaves*. **Draw** mature radish at end of first year's growth: swollen *taproot*; *branch roots*; swollen *hypocotyl*; *cotyledons*; *foliage leaves*. Compare storage organs of dandelion, beetroot, and turnip.

WOODY PLANTS

Draw a branch twig of the sycamore (*Acer Pseudo-platanus*) in its winter condition: *terminal bud* covered with *scales*; *axillary buds*; *foliage leaf-scars*; *lenticles*; *scars* from scales of former terminal buds. Mark the increments of growth of successive years. Cut longitudinally through the middle of several terminal buds of the sycamore. Examine the cut surfaces with a hand-lens. The buds will be found to be either *vegetative* or *inflorescence* buds. **Draw** cut surface of vegetative bud: *bud-scales*; *hairs*; small *foliage leaves* in the centre; short *internodes*; *vascular channels*. **Draw** cut surface of inflorescence bud; it is larger than the vegetative bud and contains developing *flowers* in the centre. The buds of horse-chestnut may be used for this work; they should be soaked in methylated spirit to dissolve away the sticky secretion.

Twigs of trees kept in water in a warm room will ' burst ' their buds; the details of the opening and development of the bud scales can then be observed before they fall off.

Examine twigs of the following trees and fill in the details:

Tree	*Buds*	*Arrangement of Buds*	*Growth of Stem*	*Development of Buds*
Sycamore (*Acer Pseudo-platanus*)	Moderate size. Green colour	Borne in opposite pairs (*decussate*)	Vegetative twigs monopodial. Flowering twigs sympodial	Bud scales are leaf-bases of undeveloped foliage leaves. Opening buds take up erect position
Horse-Chestnut (*Aesculus Hippocastanum*)				
Ash (*Fraxinus excelsior*)				
Lime (*Tilia europaea*)				
Elm (*Ulmus campestris*)				
Beech (*Fagus sylvatica*)				
Hazel (*Corylus Avellana*)				
Oak (*Quercus Robur*)				
Alder (*Alnus glutinosus*)				
Lilac (*Syringa vulgaris*)				
Cherry (*Prunus cerasus*)				

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PLANT MORPHOLOGY

THE STEM

1. Cut longitudinally through the middle of a brussels sprout. This is an example of a summer bud in which the internodes remain short. **Draw** the cut surface under a hand-lens: *growing point* with overlapping *foliage leaves*; older *foliage leaves* with *axillary buds*; *internodes*; *desmogen strands*; mature *vascular strands.*

2 (*a*) For microscopic examination of herbaceous dicotyledon stem, cut transverse sections from mature stem of sunflower (*Helianthus*). Stems preserved in alcohol are best, mount in Schultze's solution. To make permanent preparations see method described on page 9. **Draw** a plan under low power: *epidermis*, outer and inner *cortex*; *stomata*; *hairs*; *endodermis*; *pericycle fibres*; *xylem* and *phloem* on same radii; *fascicular cambium*; *medullary rays*; *interfascicular cambium* which may have formed small bundles of xylem and phloem; *pith.*

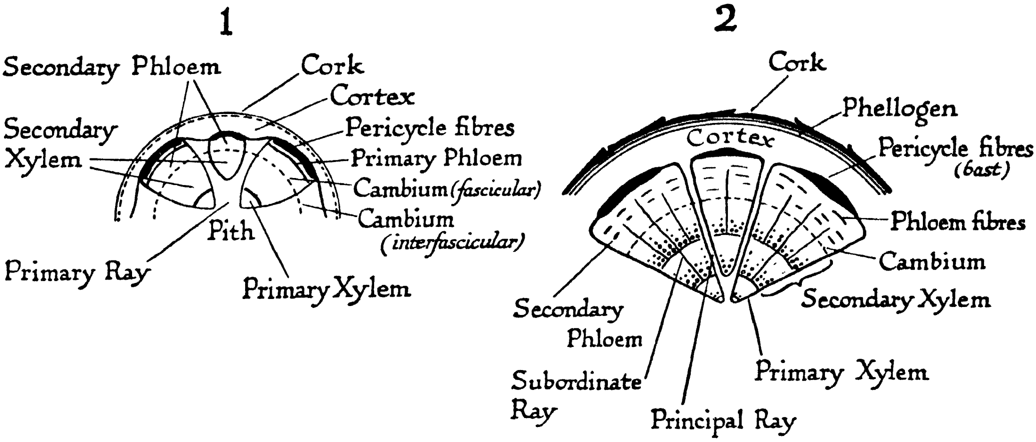

Fig. 13. The stem.—Diagrams illustrating stages in secondary growth

(*b*) Make separate drawings of the following parts under high power:

- (i) Epidermis with *cuticle* (yellow or brown); *stoma*; *hairs* (simple and glandular).
- (ii) Cortex; *collenchymatous cells* (blue); *parenchymatous cells* (blue).
- (iii) Endodermis with starch grains (dark blue); *pericycle fibres* (yellow[1]).
- (iv) Phloem with *sieve tubes* (blue), *sieve plates, companion cells*; *xylem* (yellow), *metaxylem* and smaller *protoxylem* next to the *pith*; *cambium.*

3. (*a*) From a radial longitudinal section **draw** under high power:

- (i) Phloem with *sieve tube, sieve plate,* and *companion cell.*
- (ii) Metaxylem with *pitted* vessels and adjoining *parenchyma* and *fibres.*
- (iii) Protoxylem with *spiral* vessels and adjoining *parenchyma.*

(*b*) Stain a section with aniline chloride and NOTE the lignified tissues stained yellow.

(*c*) Stain another section with alcoholic phloroglucin solution; the lignified tissues will now be stained red.

4. For microscopic examination of monocotyledon stem, cut transverse sections

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[1] The tint of these fibres may vary to brown, or even to pink.

from the stem of maize (*Zea Mays*) or Solomon's seal (*Polygonatum*) preserved in alcohol. Mount in Schultze's solution. NOTE under low power: *cortex* (*sclerenchyma*); *stomata*; numerous small *vascular bundles* near the perimeter, less numerous and larger near the centre; ground tissue (*parenchyma*). **Draw** under high power a large vascular bundle: V-shaped *xylem*; *phloem* between limbs of V; sclerenchymatous *sheath* surrounding the bundle. There is no cambium.

5. For microscopic examination of woody dicotyledon stem, cut transverse and longitudinal sections from three- or four-year-old lime (*Tilia europaea*). Mount in glycerine. For making permanent preparations see methods described on pages 9 and 10. **Draw** a plan under low power: *cork*; *phellogen*; *cortex*; *pericycle fibres*; *phloem* with *fibres*; *xylem* divided up into annual rings with spring and autumn wood; principal and subordinate *medullary rays*; *cambium*. These should be drawn as seen in transverse and longitudinal tangential and radial sections.

6. Examine a segment from the stem of an oak. NOTE: *annual rings*; position of *cambium*; *heartwood* and *sapwood*; *medullary rays*; *lenticles*; *phellogen*.

FOLIAGE LEAVES

A. The Morphology of the Leaf.

1. The main forms of leaf may be drawn from the following examples:

Simple.

Privet (*Ligustrum vulgare*): *lanceolate* shape; edge *entire*; *pinnate* venation.

Oak: *oval* shape; edge *lobed*; *pinnate* venation.

Grass: *linear* shape; *parallel* venation.

Gorse (*Ulex europaeus*): *needle* shaped; note the spine-shaped branch stems growing from the leaf axils.

Daisy (*Bellis perennis*): *spatulate* shape; edge *entire*; *pinnate* venation.

Pansy (*Viola tricolor*): *oval* shape; edge *crenate*; *stipules* (always two) have edges more prominently indented.

Sycamore: five-lobed, *crenate* edge; *palmate* venation.

Nasturtium (*Tropaeolum*): *peltate* blade; edge *entire*; cylindrical *petiole*.

Compound.

Lupin: edge of leaflets *entire*; *palmate* venation.

Ash: edge of leaflets *serrate*; *pinnate* venation.

Buttercup (*Ranunculus repens*): edge of leaflets *dentate*; *palmate* venation; sheathing leaf-base round axillary bud.

Sweet pea has stipulate, pinnately compound leaves in which all but the lowest pair of leaflets are modified into *tendrils*. Heather is an example of a plant with leaves rolled backwards. The leaves of lavender show *hairs*; examine these with a hand-lens. Succulent leaves are well illustrated in *Mesembryanthemum* which is so common along the south coast (*Cacti* have succulent *stems*).

2. Examine a branch stem of any deciduous tree covered with leaves in summer and NOTE the *leaf mosaic*. Keep in the dry, when the branch and leaves will die; the latter will not, however, become detached since leaf fall (*defoliation*) is an *active* process.

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B. Phyllotaxis (Gk. *phyllon*, leaf; *taxis*, arrangement).

The arrangement of leaves on a stem may be represented for convenience by a fraction. To obtain this fraction, tie a piece of cotton on the petiole at one node, pass the thread round spirally, in a clockwise direction, to the next node above, and so on, using the shortest spiral path, until you reach a petiole vertically above the one from which you started. The numerator of the fraction is the number of times the stem has been encircled; the denominator is the number of internodes traversed *en route*.

We may represent this diagrammatically as follows:

Beech, $\frac{1}{3}$. Three successive internodes traversed in passing to node vertically above the first. Stem encircled once. The leaves are arranged alternately and are borne in three vertical rows.

Rose, $\frac{2}{5}$. Successive nodes are separated by intervals equal to two-fifths circumference of stem. The leaves are arranged alternately.

Work out the phyllotaxis fractions for hazel, sycamore, groundsel, plantain, Canterbury-bell (*Campanula medium*). Make diagrams for each as shown in Fig. 14.

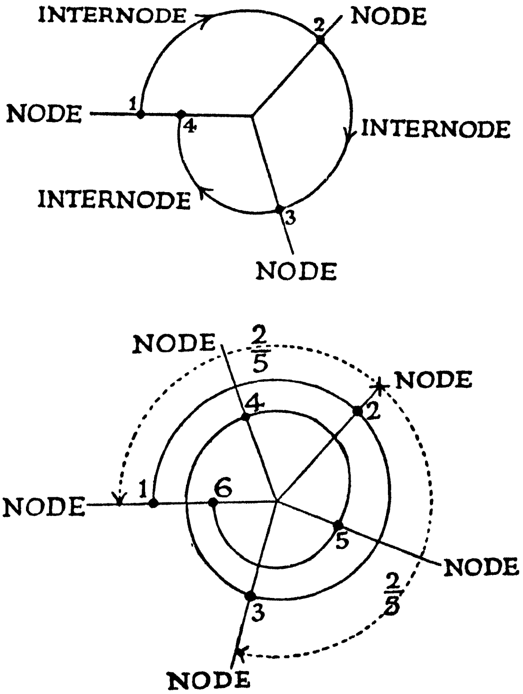

Fig. 14. Phyllotaxis of beech and rose

C. Leaf Structure.

1. Remove a portion of the stem, with leaf attached, of a geranium (*Pelargonium*), and place in an aqueous solution of eosin. After a while the eosin will be found in the xylem and seen in the veins of the leaf.

2. (*a*) Cut transverse sections across the blade (*lamina*) and midrib of a leaf of privet (*Ligustrum vulgare*): support the leaf blade in pith or roll the blade round and cut across the folds: mount in glycerine or in Schultze's solution. **Draw** from transverse section a plan under low power: *upper epidermis* with *cuticle*; *palisade cells*; *parenchymatous cells*; *vascular bundles* in transverse and longitudinal section; *lower epidermis* with *cuticle* and *stomata*.

(*b*) **Draw** under high power:

(i) Palisade cells with *chloroplasts*; *nuclei*; narrow *intercellular spaces*.

(ii) Main vascular bundle in the midrib; *xylem* towards top surface, narrow *protoxylem* at the edge of the bundle; *phloem* with *sieve tubes* and *companion cells*; *fibres*; *sheathing cells* round the bundle;

surrounding *parenchymatous cells* which may have *chloroplasts*; large *intercellular spaces.*

(iii) Stoma and guard cells as seen when cut transversely; *pore*; *guard cells* with *chloroplasts*; *cells* of *lower epidermis* with cutinized outer walls.

3. (*a*) Strip off the epidermis from an iris leaf. Mount in dilute glycerine with outer surface uppermost. **Draw** under high power: two *guard cells*; *pore*; *vestibule* formed between overlying epidermal cells.

(*b*) **Draw** under high power the same structures as seen in prepared transverse sections.

4. Examine transverse sections of xerophytic leaves such as heather which is rolled, and holly which has thick continuous cutinized epidermis; also hydrophytic leaves, such as water lobelia, which has thin-walled epidermis and air-spaces. Examine leaves of water crowfoot (*Ranunculus aquatilis*), those submerged are thin and threadlike, whilst the floating leaves are broad and thin.

THE ROOT

1. Examine roots of groundsel; wash away the soil clinging to the roots and mount end portion of main taproot or lateral root in water on slide. **Draw**: *root cap* covering embryonic cells; elongating region; region of *root hairs.* Focus on the centre of the root and note region where differentiation into *vascular cylinder* commences and renders it visible.

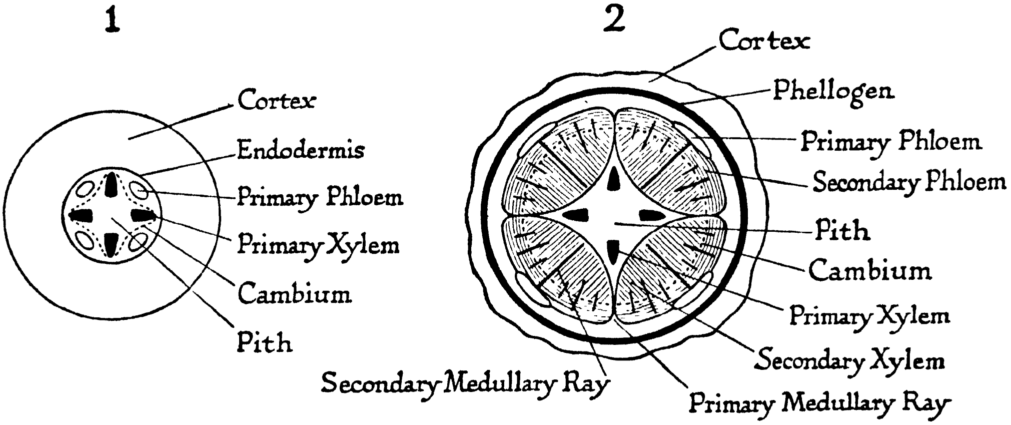

Fig. 15. The root.—1. Diagram illustrating arrangement of tissues before cambial divisions begin
2. The same after secondary thickening has taken place

2. Roots of the bean (*Vicia Faba*) provide good material for microscopic examination. Cut sections from the roots of seedlings and mount in Schultze's solution; permanent sections may be made using method described on page 9.

(*a*) *Longitudinal section of root tip.* **Draw** under low power a plan marking position

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of *root cap*; *meristematic cells*; *cells* stretched by *vacuolation.* **Draw** cells from each of these regions under high power.

(*b*) *Transverse section in region of root hairs.* **Draw** under low power a plan of section: *root hairs*; *cortex*; *endodermis*; *pericycle*; *xylem*; *phloem*; *pith.*

(*c*) Make separate drawings of the following parts under high power:

(i) Piliferous layer: *root hairs*; *parenchymatous cells* of cortex with starch grains.
(ii) Endodermis with cutinized lateral walls.
(iii) Xylem strand with *protoxylem* and larger *metaxylem.*
(iv) Phloem with *sieve plate* and *companion cell.*
(v) Parenchymatous *pith cells.*

(*d*) *Transverse section in region of branch roots.* NOTE that the branch roots are in lateral rows on the main taproot. **Draw** under low power: *primary xylem*; *secondary xylem*; *cambium*; *secondary phloem*; *primary phloem*; *pericycle*; *endodermis*; *cortex*; *branch root,* opposite xylem strand, with *embryonic cells* near its tip; ruptured cortical cells; *medullary ray* on same radius as primary xylem.

(*e*) In longitudinal section in region of branch roots, NOTE *spiral thickening* on walls of xylem and developing *branch roots.* Transverse sections may be cut from small branch roots of the sycamore in order to show concentric rings of growth.

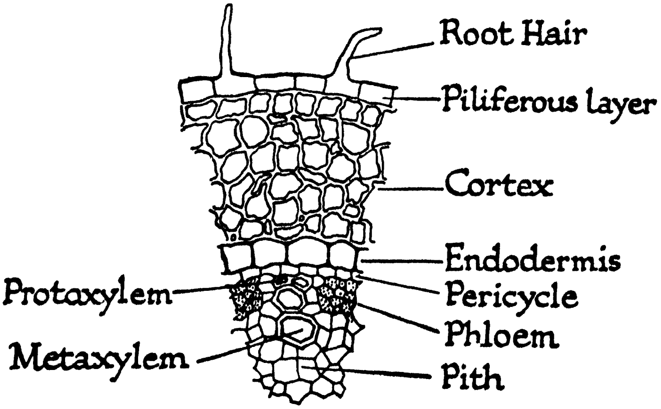

Fig. 16. The root.—Detailed segment in region of root hairs

3. Cut transversely across a carrot and NOTE region of *cambium* and *parenchymatous cells* forming tissue for food storage. Examine transverse section across root of water lily (a *hydrophyte*) and NOTE *air-spaces.*

4. *Transverse section of root of a Monocotyledon.* **Draw** section of maize (*Zea Mays*) under low power: *root hairs*; *cortex*; *endodermis*; *pericycle*; many *xylem groups* alternating with *phloem groups*; *pith.* There is no cambium.

5. **Mitosis (Karyokinesis).** The process of cell division is best seen in longitudinal sections from the growing region of root of bean or onion. **Draw** the following stages from prepared sections under high power or oil immersion:

(*a*) *Prophase* with *chromosomes, asters,* and *spindle.*

(*b*) *Metaphase* with dividing chromosomes on *equatorial plate.*

(*c*) *Anaphase* with daughter chromosomes.

THE FLOWER

In studying flowers, the procedure is:

1. Determine the floral formula.
2. Draw the floral diagram.
3. Draw from longitudinal section through the flower.
4. Examine the separate parts.

1. **Floral formula.** The following are the conventional symbols and signs used:

K = calyx
C = corolla
P = perianth (calyx + corolla)
A = androecium (stamens)
G = gynoecium (carpels)
↓ = zygomorphic flower
No arrow = actinomorphic flower

( ) around a number indicates the parts are *joined*
∞ = indefinite number
Two numbers joined by + = the parts are in *separate* whorls
$\bar{G}$ = inferior ovary (*epigynous*)
$\underline{G}$ = superior ovary (*hypogynous*)
G with no mark indicates the flower is *perigynous*

Examples.

Buttercup $K_5C_5A\infty\underline{G}\infty$ Sweet pea $\downarrow K_{(5)}C_5A_{(9)+1}G1$ Tulip $P_{3+3}\,A_{3+3}\,\underline{G}(3)$

2. **Floral diagram.** This represents an imaginary transverse section across a flower, and shows in plan the arrangement of all the parts. **Draw** lightly five concentric circles (Diagram A of Fig. 17). First put in the axis (stem from which the flower stalk grows), bracts and any bracteoles in their correct position. Now start putting in the whorls on the corresponding circles, being careful to draw their relative positions correctly (Diagram B of Fig. 17). Since there are often two whorls of stamens, two

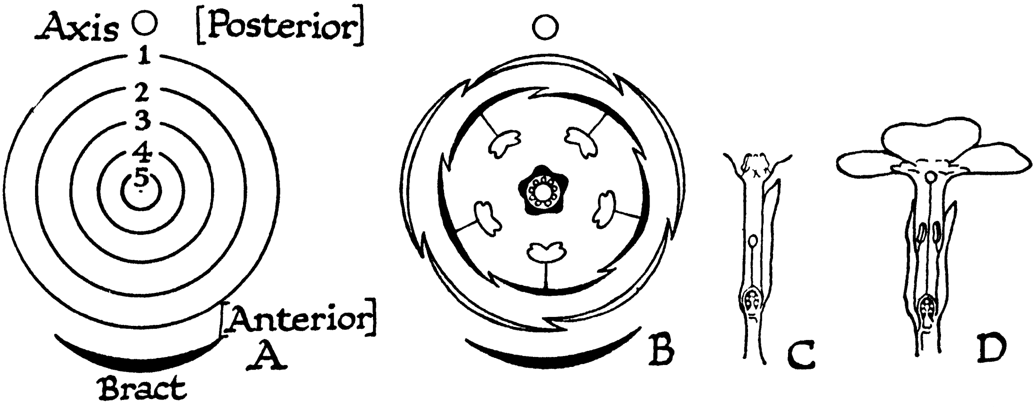

Fig. 17. Flower of primrose.—A. Floral diagram commenced. Circle 1 for sepals; circle 2 for petals; circles 3 and 4 for stamens; circle 5 for carpels. B. Floral diagram completed. C. Longitudinal section through thrum-eyed flower commenced. D. Longitudinal section through pin-eyed flower completed

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circles are reserved for them. The buttercup has an indefinite number of stamens arranged spirally; they should be drawn *between* Circles 3 and 4. Pay particular attention to the placentation of the ovary.

3. **Longitudinal section.** Cut the flower into two similar halves, starting from the stalk and cutting upwards. Now draw the *section* to scale, starting from the centre and working outwards to prevent overcrowding of the important central parts (Diagram C of Fig. 17). The object of the drawing is to show the arrangement of the parts, therefore draw those which have been cut through and only such other parts as are important (Diagram D of Fig. 17). To draw *half the flower* would result in a confused drawing in which the arrangement would not be clear.

4. Separate parts can now be removed from the various whorls and examined under hand-lens or microscope.

PRACTICAL WORK

Flower of Buttercup (*Ranunculus repens*). Creeping stem.

1. Examine plant. NOTE. Spreading *calyx* (reflexed in *R. bulbosus*); flower stalk (*peduncle*) furrowed; *bracts, bracteoles*; *receptacle*; *sepals*; *petals*; *stamens*; *carpels* which are not fused (*apocarpous*).

2. Work out floral formula. **Draw** floral diagram. Cut longitudinal section (the flower is actinomorphic) and **draw.** NOTE stages in the development of the flower which is incompletely *protandrous*; self-pollination is possible.

3. Remove the following parts from the flower and **draw**: *sepal* with *hairs*; *petal* with *nectary*;[1] *stamen* with *anther* and *filament*; *carpel* with *ovary, style,* and *stigma.* Place a single carpel on a microscope slide and under low power NOTE: *stigmatic surface* and single *ovule* with *basal placentation* seen through the transparent wall of the ovary. After removing all the sepals and petals, NOTE the *scars* left on the receptacle and the very short *internodes.*

4. **Microscopic examination. Draw** from prepared slide of transverse section across anther of buttercup: four pollen *sacs*; *pollen grains* (*microspores*); *vascular bundle*; *fibrous layer* in walls of pollen sacs; line of dehiscence.

5. (*a*) Examine pollen grains of the tulip, mounted in dilute glycerine, under high power. NOTE the double cell walls and the granular protoplasm which hides the two nuclei.

(*b*) Put some fresh pollen grains of the tulip to germinate in 5 per cent cane sugar solution in water and leave in the dark. Examine after twelve hours for pollen tubes.

(*c*) Examine any prepared slides showing germinating pollen tubes in the walls of the stigma. With suitable stains, the two male gametes and the nucleus of the pollen grain near the tip of the tube can be made out.

6. (*a*) From transverse section across carpel of marsh marigold (*Caltha palustris*), **draw** under low power: *wall* of carpel; *midrib*; *ovule*; *placenta.* NOTE that there are two rows of ovules joined to the edges of the carpellary leaf. The ovules of the two rows alternate.

(*b*) Under high power **draw** section through the ovule: *outer* and *inner coats*; *nucellus*; *embryo sac* containing large *secondary nucleus,* conspicuous *antipodal cells, egg cell,* and *synergidae*; *vascular bundle.* The section may also have passed through the *micropyle* which is the same end as the placenta.

7. Examine any prepared slides showing development of the embryo sac after fertilization.

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[1] The nectary produces *nectar,* which is a sugary solution; honey is made from this by the bee.

THE FRUIT

After fertilization development takes place as follows: the *fertilized egg* gives rise to the *embryo* and the *secondary nucleus* divides to form the *endosperm.* The *ovule* becomes the *seed,* the *coat* of the *ovule* becomes the *testa,* the *nucellus* may become the *perisperm.* The *wall* of the *ovary* becomes the *pericarp.* **Dry fruits** are produced when the *pericarp* becomes hard and dry, **succulent fruits** are produced when the *pericarp* develops soft and fleshy cells.

The main types of *true fruits* may be drawn from the following examples:

DRY FRUITS.

Single seeded. These are often confused with seeds. One-seeded dry fruits have *two* coats (*pericarp*+*testa*) and *two* scars on the outer coat (remnants of *stigma* and *flower stalk*). Seeds have *one* coat (*testa*) and *one* scar (*hilum*). One-seeded dry fruits are *indehiscent.*

Achene: Buttercup; dandelion with tuft of hairs (*pappus*); maize.

Nut: Oak; hazel; beech.

Samara (winged nut): Elm; ash. The fruit of the sycamore usually has two *wings* with a seed at the base of each. The *fruit* splits into one-seeded portions (*schizocarp*). NOTE in developing wings of the ovary that each carpel originally contains two ovules.

Many seeded. These are *dehiscent.*

Follicle (single carpel, dehisces along *inner* edge): marsh marigold; columbine.

Legume (single carpel, dehisces along *both* edges): broad bean; pea; laburnum. Split the carpels down and NOTE the *marginal placentation.*

Capsule (two or more carpels fused, dehisce in various ways): iris, dehiscence by *valves*; campion, dehiscence by *teeth*; poppy, dehiscence by *pores*; scarlet pimpernel, dehiscence by a *lid.* The *siliqua* is a modified capsule in which the carpel walls split away from the placentas and leave the seeds attached to a false septum. *Example,* the wallflower.

SUCCULENT FRUITS.

Berry (*pericarp* forms outer skin, or *epicarp,* and a fleshy *mesocarp*). Orange; banana; gooseberry; tomato; the date is a single-seeded berry in which the endosperm of the seed becomes very hard. NOTE calyx and flower stalk on outside of the gooseberry, cut across transversely and NOTE two marginal placentas. Distinguish the two layers of the pericarp.

Drupes (*pericarp* forms *epicarp, mesocarp,* and a hard inner layer, the *endocarp*). Plum; cherry; walnut; coconut. The raspberry and blackberry are collections of *drupelets* formed from apocarpous flowers. NOTE on outside of plum: *scars* from stigma and flower stalk. Cut longitudinally through fruit and distinguish the three layers of the pericarp.

SPERMOPHYTA

FALSE FRUITS.

The succulent portion of the fruit is formed from the floral *receptacle.* The outline of the ' core ' marks the ovary wall in the apple and pear. Cut longitudinally through ripe apple or pear. NOTE: *ovary wall*; *seeds*; fleshy *receptacle*; withered *styles*; *calyx* and flower *stalk.* The receptacle forms the fleshy part of the strawberry and rose hip, the true fruit of each is a collection of achenes.

THE SEED

Micro-tests for food substances stored in seeds may be made by cutting thin sections from the seed, mounting in a drop of water on a microscope slide, and noting any change of colour when the following reagents are added: Sudan 3 (oils *red*), 1 per cent osmic acid (oils *black*), Schultze's solution (starch *dark blue*, cellulose *pale blue*), Millon's reagent (proteins, *red*).

Tests for proteins, monosaccharides, and disaccharides are carried out as test-tube reactions; see page 126.

1. **Broad bean seed** (*Vicia Faba*): *non-endospermic, hypogeal cotyledons* (in seedlings).

(*a*) **Draw** seed after soaking in water for several hours: *testa*; *hilum*; *micropyle,* found by squeezing out a drop of water. NOTE any seeds showing emergence of *radicle* through ruptured testa.

(*b*) Peel off the testa and remove one cotyledon. **Draw** remaining parts: fleshy *cotyledon*; *epicotyl, radicle.* Test the cotyledon for starch.

2. **Vegetable marrow seed** (*Cucurbita*): *perispermic, epigeal cotyledons.* NOTE scar of attachment and micropyle. Split seed longitudinally. **Draw:** greenish layer of *perisperm*; thick *cotyledon*; *epicotyledonary bud*; *radicle.*

3. **Castor oil seed** (*Ricinus*): *endospermic, epigeal cotyledons.*

(*a*) **Draw** seed from outside: hard *testa*; *caruncle,* which hides hilum and micropyle. Wax over the caruncles of several castor-oil seeds. Compare the gain in weight when these are left to soak in water for several hours with the gain in weight of others which are unwaxed and are left to soak for the same period.

(*b*) Cut longitudinally through caruncle and seed. Remove one cotyledon. **Draw:** *endosperm*; thin *cotyledon* with *veins*; *radicle*; *epicotyledonary bud.* Test the endosperm for oils and note the large *aleurone grains* which it contains.

4. **Grain of maize** (*Zea Mays*): This is an *achene* in which the *pericarp* is closely united with the *testa* (*caryopsis*). *Endospermic, hypogeal cotyledon.*

(*a*) Distinguish on the outside of a grain: *stigma*; point of attachment to flower at opposite end; oval white depression which marks position of embryo. Remove the outer coat from a grain soaked in water, make a slit along the envelope enclosing the embryo and fold back the edges of the *cotyledon* which is seen to wrap round *plumule* and *root sheath.*

(*b*) Halve a grain by cutting through it longitudinally. **Draw** the cut surface: *radicle*; *plumule*; shield-shaped *cotyledon* (*scutellum*); *endosperm,* white and soft near the scutellum, the remainder portion yellow and harder. Test the yellow endosperm for sugars and the white endosperm for starch.

5. Sketch stages in the development of seedlings with epigeal and hypogeal cotyledons. Details for setting up germination experiments will be found on page 67.

FAMILIES OF FLOWERING PLANTS

Work out the floral formula for each of the following examples, then draw floral diagram and longitudinal section. When assigning a flower to its family a British Flora should be consulted. *A School Flora* by W. M. Watts is recommended.

(A) DICOTYLEDONES

The families in this class are characterized by having two cotyledons in the embryo and members of the floral whorls in fours or fives. The leaves show a variety of form; they are simple or compound and have midrib with branch veins.

(*a*) *Polypetalous* (*petals free*) *and Apetalous* (*petals absent*) *Families*

1. **Ranunculaceae.** With the exception of clematis, the plants are herbs with poisonous juices. The flowers are hypogynous, protandrous, and are pollinated by a variety of insects (*entomophilous*).

Examples.

Anemone (*Anemone nemorosa*). One whorl in the perianth, the calyx. Fruit an achene.

Larkspur (*Delphinium*). Flower zygomorphic. Fruit a follicle.

2. **Cruciferae.** Non-poisonous herbs. The flowers have cross-shaped arrangement of petals, hence the name Cruciferae (Lat. *crux*, cross; *fero*, I carry); they are hypogynous, protandrous, and are pollinated by bees. Fruit a siliqua.

Example.

Wallflower (*Cheiranthus*). Inflorescence a raceme. No bracts or bractioles.

3. **Rosaceae.** Herbs, shrubs, and trees. Great variety in floral structure and in the fruit. Cross-pollination favoured by bees.

Example.

Dog-rose (*Rosa canina*). Inflorescence a corymb. Flower perigynous. No nectar. Fruit a collection of achenes.

Compare flowers of apple (epigynous) and strawberry (slightly perigynous).

4. **Leguminosae.** The second largest family; includes trees, shrubs, and herbs. The flowers are slightly perigynous, zygomorphic, and are pollinated by insects heavy enough to open the keel.

Examples.

Sweet pea (*Lathyrus odoratus*). NOTE standard, two wing, and two keel petals. Nectar produced at base of filaments.

Broom (*Cytisus scoparius*). Flower explosive and produces no nectar.

SPERMOPHYTA

5. **Umbelliferae.** Large family, mostly perennial herbs with taproots used as a vegetable (carrot, parsnip). Inflorescence a compound umbel. Floral structure uniform. The flowers are epigynous with a nectary exposed on top of the ovary; they are completely protandrous and are cross-pollinated by small flies. Fruit a schizocarp.

Example.

Cow-parsnip (*Heracleum sphondylium*). NOTE the larger outside petals of the marginal flowers on the inflorescence.

(*b*) *Gamopetalous* (*petals fused*) *Families*

1. **Primulaceae.** Annual or perennial herbs. Floral structure uniform. The flowers are hypogynous with the stamens joined to the petals (*epipetalous*). Fruit a capsule.

Example.

Primrose (*Primula vulgaris*). NOTE 'pin-eyed' and 'thrum-eyed' flowers found on separate plants. Nectar produced at bottom of corolla tube. Flower cross-pollinated by bees.

2. **Labiatae.** Annual or perennial herbs with square, hollow stems. Floral structure uniform. The flowers are hypogynous and zygomorphic with a two-lipped corolla, hence the name Labiatae (Lat. *labia,* lip). Fruit a schizocarp, splitting up into four nutlets.

Example.

White dead-nettle (*Lamium album*). Nectar produced at base of the ovary. Flower protandrous and cross-pollinated by bees.

3. **Scrophulariaceae.** Annual or perennial herbs. Floral structure not uniform but some flowers are two-lipped like those of the Labiatae. A superior two-celled ovary is the most constant feature. Fruit a capsule.

Example.

Foxglove (*Digitalis purpurea*). Poisonous plant. Nectar produced at base of the ovary. Flower protandrous and cross-pollinated by humble-bees.

4. **Compositae.** The largest family, includes annual or perennial herbs. Inflorescence uniformly a capitulum with an involucre of bracts. Flowers epigynous and protandrous. Calyx absent or represented as a pappus on the fruit, which is an achene.

Examples.

Dandelion (*Taraxacum*). All the florets are strap-shaped. **Draw** vertical sections through the florets showing the development of the stigmas, which may be self-pollinated.

Daisy (*Bellis perennis*). Strap-shaped and tubular florets. **Draw** vertical section through ray-floret; *strap-shaped corolla*; *carpel*; no stamens. **Draw** vertical section through disc-floret; *tubular corolla*; *carpel*; *fused stamens*.

Thistle (*Carduus lanceolatus*). All the florets are tubular with long corolla tube.

NOTE bristles between the florets and prickly nature of the involucre.

(B) MONOCOTYLEDONES

The families in this class are characterized by having one cotyledon in the embryo and members of the floral whorls in threes. There is no distinction in the perianth between corolla and calyx. The plants are usually herbs forming bulbs, corms, or rhizomes. The leaves are simple with parallel veins and are narrow and sheathing. There is no cambium.

1. **Liliaceae.** Perennial herbs. Flowers regular and hypogynous. Fruit a capsule or berry.

Example.

Tulip (*Tulipa*). Solitary flowers. Stem with sheathing leaves.

Compare the bluebell (*Scilla nutans*), of which the inflorescence is a raceme.

2. **Amaryllidaceae.** This family resembles the Liliaceae except that its flowers are epigynous.

Example.

Daffodil (*Narcissus*). There is a petaloid perianth of six segments within which is the tubular corona.

Compare the flower of the iris, which belongs to the family Iridaceae and has only three stamens.

3. **Gramineae.** Annual or perennial herbs. Flowers regular and hypogynous. Lodicules possibly represent a reduced perianth. Inflorescence variable. Fruit an achene with pericarp and testa fused (*caryopsis*).

Example.

Oats (*Avena sativa*). The 'ear' is an inflorescence (*spikelet*) enclosed in scales (*glumes*). Each flower of the inflorescence is enclosed between bract and bractiole (*pales*). **Draw** vertical section with lower pale (bract) removed: *upper pale*; three *anthers*; two-lobed feathery *stigma*; *ovary*; *lodicule*. The flower is wind-pollinated (*anemophilous*).

SPERMOPHYTA

Germination. Conditions for germination may be studied by placing seeds between the walls of a glass jar and a roll of blotting-paper filled with sawdust or fine sand (Fig. 18).

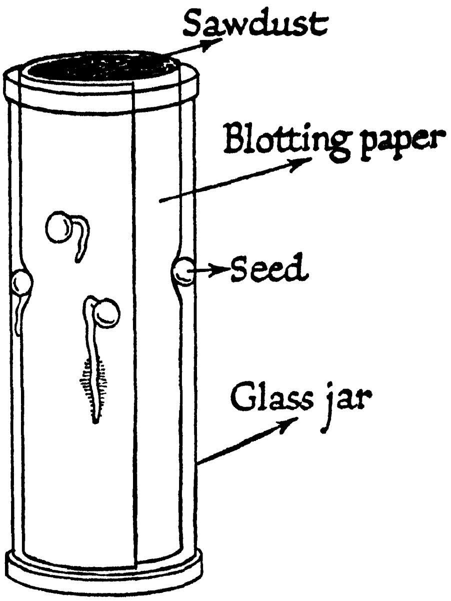

Fig. 18 Germination

1. Soak a few peas in water for several hours and then place them, spaced out, in the jar. Keep the blotting-paper moist by pouring water into the sawdust from time to time. Leave in a warm room and in the light. NOTE: appearance of *plumule, root hairs, branch roots*, and fate of the *cotyledons*.

2. Repeat as for Experiment 1. Keep the blotting-paper moist and leave the jar in a warm but dark place. NOTE appearance of *etiolated* plants.

3. Use dry seeds and do not water the sawdust. Will the seeds germinate when the jar is exposed to light and warmth?

4. Place a few seeds near the bottom of the jar and pour in water until they are covered. Will the seeds germinate when the jar is exposed to light and warmth?

5. Sow mustard seeds on damp blotting-paper. Leave exposed to air, light, and warmth. NOTE the *root hairs*.

Growth: Tropisms.

6. *Geotropisms* of stem and root may be observed by clamping a jar containing germinating seeds in any desired position and keeping in the dark in order to eliminate the influence of light. That roots are sensitive to solid particles may be shown by placing small stones between the blotting-paper and glass sides of the jar.

7. *Phototropism* of stem may be seen by clamping a jar containing seedlings with projecting and erect stems in a horizontal position and directing light on them by means of a mirror so that the rays are also horizontal. The stems will grow out *obliquely* under the dual influence of light and gravity.

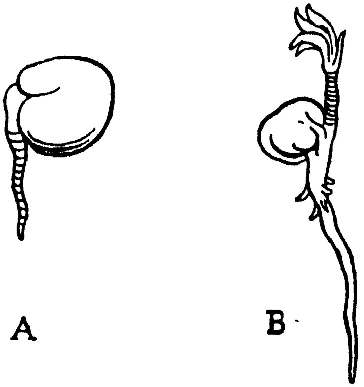

Fig. 19. Distribution of growth.—A, in root; B, in stem

Distribution of Growth.

8. Remove some healthy seedlings from the germinating jars and mark on root and stem parallel lines, equally spaced (Fig. 19). This is best done in Indian ink and by means of a cotton thread stretched between

the ends of a metal spring (Fig. 20). Replace in the jar and note the relative elongations of the intervals, indicating the regions of growth in root and stem.

Metabolism.

9. *To show the respiration of seeds.* Place some peas in a flask with a little water. Connect the flask with a delivery-tube leading to a beaker full of water. Suspend in the flask a small test-tube containing caustic potash (Fig. 21). As the seeds respire, carbon dioxide is absorbed by the potash. Since the oxygen in the flask is used up, water rises in the delivery-tube from the beaker to take its place.

10. *To show that roots give off carbon dioxide.* Place the roots of some healthy seedlings in a jar containing water with a little Congo red added (Fig. 22). The Congo red being sensitive to carbon dioxide will change colour. This change should be contrasted with a control mixture without seedlings.

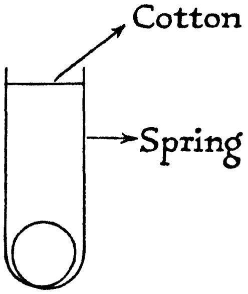

Fig. 20

11. *To show that oxygen is given off during photosynthesis.* Cover some water-weed (*Elodea*) placed in water with a funnel and test-tube also filled with water (Fig. 23). When placed in sunlight, the oxygen evolved rises and fills the test-tube. Identify the oxygen by means of a glowing splint. It is a good plan to add a trace of sodium carbonate to the water.

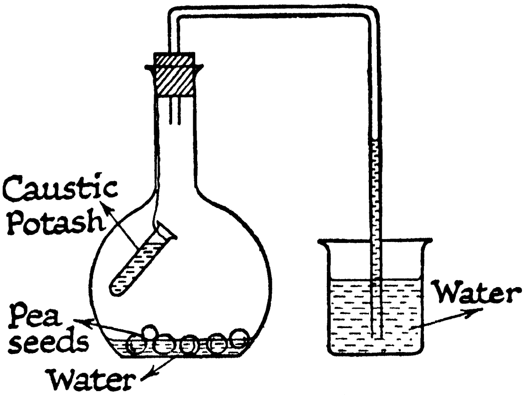

Fig. 21. Respiration of seeds

12. *Starch prints.* 'Nasturtium' leaves (*Tropaeolum*) may be shown to contain starch after exposure to sunlight, and work well in the following experiment. Cover a portion of a leaf on a growing nasturtium plant, which has previously been kept in the dark for twelve hours, with light-proof paper. Use two strips of the paper and hold them in position on each side of the leaf by means of small metal clips (Fig. 24). Leave plant exposed to sunlight for several hours. Remove leaf, kill by immersion in hot water, and then extract the chlorophyll by boiling in 90 per cent alcohol. Immerse the decolorized leaf in iodine solution and then in benzene. The latter will remove all the brown stain but leave the dark blue colour due to the starch formed in the leaf. The leaves of many monocotyledons will be found to contain no starch even after exposure to sunlight.

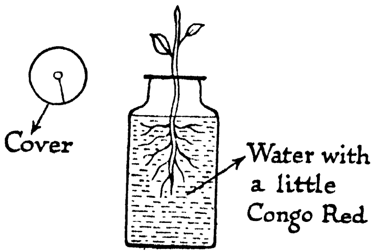

Fig.22. Evolution for cabon dioxide from roots

13. *Transpiration.* The following experiments may be carried out with the leaves and stem of *Euonymus* which is available all the year round. When required for use, the stems should be freshly cut under water.

(*a*) The stem of a leafy shoot is fitted through a cork and dips into water which is contained in a long glass tube inverted over a beaker of mercury. To ensure good joints the top of the cork is painted over with molten paraffin wax (Fig. 25). As the plant uses up the water, the mercury rises in the tube. The physical counterpart of this experiment may be demonstrated as follows. Fill a thistle funnel loosely with plaster of paris, since it expands on hardening. The stem of the funnel should then be filled with water, using a very fine pipette, and immersed in mercury (Fig. 25). The mercury will slowly rise up the stem to take the place of the water which evaporates from the funnel.

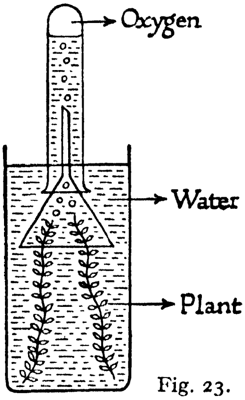

Fig. 23.
Evolution of oxygen during photosynthesis

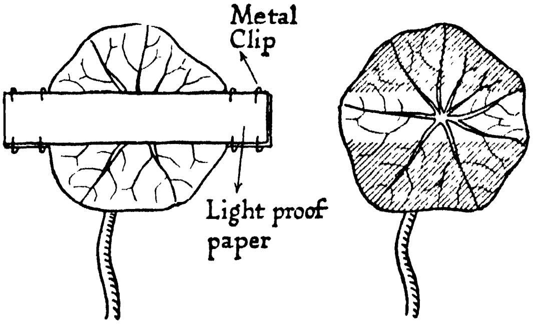

Fig. 24. Starch prints

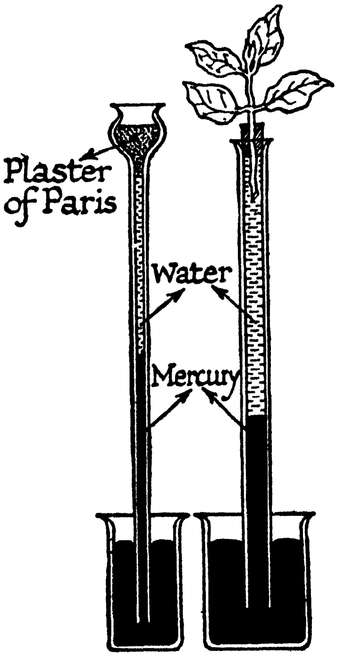

Fig. 25. Transpiration

(*b*) More exact experiments on transpiration may be carried out with a **potometer** shown in Fig. 26. A wide-necked bottle is fitted with a cork through which runs (i) a glass tube to carry the living shoot, (ii) a narrow glass tube fitted with a stopcock leading to a cylindrical funnel, and (iii) a capillary tube bent at right angles with a scale attached to the horizontal portion.

To set the apparatus, the stopcock is opened and water poured into the funnel until the bottle and two tubes are filled and overflow. The stopcock is then closed and a small cork, through which runs the stem of the leafy shoot, fitted into the wide end of the glass tube, so that the stem dips into the water.

As the plant absorbs water from the apparatus, a column of air will creep along the capillary tube. Since the rate of absorption is proportional to the rate of transpiration, we can get a measure of the latter by timing the end of the air column as it passes between measured points on the scale. A final result is obtained by taking the average of several readings. The apparatus is reset by opening the stopcock and letting water run in until all the air is driven out of the capillary tube.

Compare the rates of transpiration when the potometer is placed

- (i) in still air and indirect light;
- (ii) in still air and direct sunlight;
- (iii) in a breeze and indirect light;
- (iv) in a breeze and direct sunlight.

Reduce the transpiring surface by removing some of the leaves or vaselining over their under surfaces. Remove the tube carrying the plant and substitute for it a thistle funnel filled with plaster of paris and stem filled with water. Investigate how the rate of evaporation is affected when the apparatus is subjected to the same conditions as before.

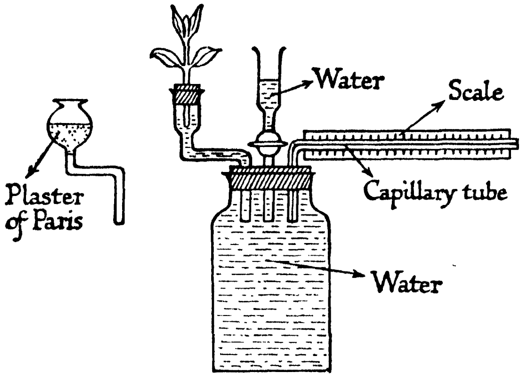

Fig. 26. Potometer

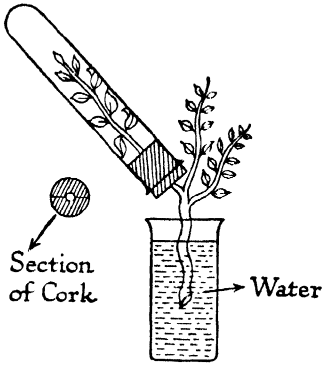

Fig. 27. Transpiration

14. (*a*) *To show that leaves give off water.* Surround some growing leaves with a large dry test-tube as in Fig. 27. Make a hole in the cork to carry the stem, and then cut the cork longitudinally so that it may be fitted round the stem when the shoot has been placed in the test-tube. Place the main stem of the shoot in a beaker of water after making all the joints airtight by painting over with molten paraffin wax. After a while the inside of the test-tube becomes misty and drops of moisture appear. These can be identified as water by dismantling the apparatus and dusting round the sides of the test-tube with a little anhydrous copper sulphate.

(*b*) Soak some filter papers in a 3 per cent solution of cobalt chloride. After they have been thoroughly dried, note the change in colour when one of them is exposed to the water vapour in the breath. Place a leaf while still attached to its stem, which dips in water, between two sheets of cobalt paper, and keep flat between two sheets of glass. NOTE which surface of the leaf gives off most water vapour, as indicated by the change of colour.

15. *To show the presence of conducting channels in a stem.* Boil some water in a round-bottomed flask to which a few pieces of unglazed earthenware have been added to prevent

'bumping'. When the water has boiled for a few minutes and the flask is full of steam, remove the source of heat. Stopper the flask immediately with a well-fitting cork through which runs a delivery-tube attached at the other end to a piece of stem. The stem must have nearly the same diameter as the delivery-tube, and is attached to it by a piece of rubber tubing (Fig. 28). Wax over all joints and all of the stem except the two cut ends. The delivery-tube bends over in two right angles so that the stem dips into a beaker containing a little potassium permanganate in water. As the steam in the flask condenses, the permanganate solution will be drawn up through the conducting channels of the stem and will be seen to rise slowly up the delivery tube.

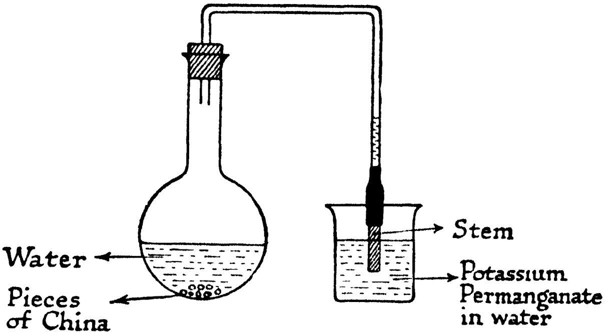

Fig. 28. Demonstration of conducting channels in a piece of stem

Cut the stem in two at the end of the experiment and note where the permanganate has stained the conducting channels. The rates of flow through various samples of woody stem may be compared by having more than one delivery-tube attached to the flask, each connected to a sample of stem. All the samples of stem used must be of the same length.

16. *To demonstrate root pressure.* Any healthy plant, such as a geranium or fuchsia, growing in a pot will serve for this experiment. Cut across the stem an inch or so above the level of the soil whilst the pot and the lower portion of the stem are kept under water. Connect the stump to a long glass tube whilst still under water, using a piece of rubber tubing and binding round the joints with wire or twine (Fig. 29). Take the plant out of water and support the glass tube in a vertical position. Mark the levels as the water rises up the tube with pieces of gummed paper. The water rises more and more slowly as it rises higher, and finally becomes stationary. Measure the maximum height reached above soil level; this gives an estimate of the root pressure in centimetres of water.

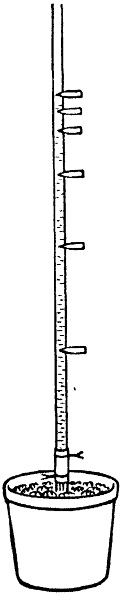

Fig. 29. Root pressure

17. *To demonstrate the mineral constituents of plant food.* This is done by water-culture experiments. Seedlings (*wheat*), or cuttings from a water-plant such as the spider-wort (*Tradescantia*), are grown in jars so that their roots obtain food material from prepared solutions.

A normal solution[1] containing the essential elements is as follows:

Distilled water	1,000 c.c.
Potassium nitrate	1·0 gm.
Magnesium sulphate	0·25 gm.

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[1] Recommended by M. A. Johnstone in *Matriculation Botany.*

Ferrous phosphate	0·5 gm.
Calcium sulphate	0·25 gm.
Sodium chloride	0·5 gm.

Comparative growths are then made eliminating each of the elements in turn from the culture solutions. Stunted growth will be noticed when nitrogen is omitted. This may be done by substituting potassium chloride for potassium nitrate in the culture solution.

CLASSIFICATION OF ANIMALS INCLUDED

PHYLUM PROTOZOA (Gk. *protos*, first; *zoon*, animal). No differentiation into tissues or cellular structure.

1. Class **Gymnomyxa** (Gk. *gymnos*, naked; *myxa*, slime). *Amoeba.*

2. Class **Ciliophora** (Lat. *cilium*, eyelash; Gk. *pherein*, to bear). *Paramecium, Vorticella.*

3. Class **Mastigophora**[1] (Gk. *mastigion*, little whip; *pherein*). *Polytoma, Trypanosoma.*

4. Class **Sporozoa** (Gk. *sporos*, seed; *zoon*). *Monocystis, Plasmodium* (*Haemamoeba*).

Phylum COELENTERATA (Gk. *koilos*, hollow; *enteron*, gut). Metazoa with two protoplasmic layers, ectoderm and endoderm (Diploblastica).

Class **Hydrozoa** (Gk. *hydor*, water; *zoon*). *Hydra, Obelia.*

Phylum PLATYHELMINTHES (Gk. *platys*, flat; *helmins*, worm). Three protoplasmic layers, ectoderm, endoderm, and mesoderm (Triploblastica). No body cavity.

1. Class **Trematoda** (Gk. *trema*, hole). *Fasciola* (*Distomum*).

2. Class **Cestoda** (Gk. *kestos*, tape). *Taenia.*

Phylum ANNELIDA (Lat. *annulus*, ring; Gk. *eidos*, form). Segmented Triploblastica with coelom and ventral nerve cord.

1. Class **Oligochaeta** (Gk. *oligos*, few; *chaite*, hair). *Lumbricus.*

2. Class **Polychaeta** (Gk. *polys*, many; *chaite*). *Nereis.*

Phylum ARTHROPODA (Gk. *arthron*, joint; *pous*, foot). Segmented Triploblastica, coelom reduced. Exoskeleton of chitin and paired jointed limbs.

1. Class **Crustacea** (Lat. *crusta*, shell). *Astacus.*

2. Class **Insecta** or **Hexapoda** (Gk. *hex*, six; *pous*). *Periplaneta, Musca, Anopheles, Pieris, Apis.*

3. Class **Arachnida** (Gk. *arachne*, spider; *eidos*). *Araneida* (Spiders).

Phylum MOLLUSCA (Lat. *molluscus*, soft). Unsegmented Triploblastica, coelom reduced. Exoskeleton of calcareous material usually adhering to a part of the skin. A mantle fold and foot present.

1. Class **Gastropoda** (Gk. *gaster*, stomach; *pous*). *Helix.*

2. Class **Lamellibranchiata** (Lat. *lamella*, thin plate; *branchia*, gills). *Anodon.*

Phylum ECHINODERMATA (Gk. *echinos*, spine; *derma*, skin). Radially symmetrical Triploblastica, well developed coelom. Skin contains calcareous plates or spines.

Class **Asteroidea** (Gk. *aster*, star; *eidos*). *Asterias.*

Phylum CHORDATA (Gk. *chorde*, cord). Notochord which may be replaced by cartilage or bone. Triploblastic, developed coelom, hollow dorsal nervous system. Gill-clefts present sometime during life.

(A) Subphylum **Cephalochorda** (Gk. *kephale*, head; *chorde*). Notochord runs whole length of body. No skull, limbs, heart, skeleton, or definite brain. *Amphioxus.*

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[1] Forms sometimes placed in this class which have photosynthetic nutrition have been classed with the plants.

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(B) Subphylum **Vertebrata** (Lat. *vertebra*, joint). Notochord does not reach front of the head and is usually reduced or lost in adult. Anterior brain-case and internal skeleton of cartilage or bone.

1. Class **Pisces.** *Scyllium.*
2. Class **Amphibia.** *Rana.*
3. Class **Reptilia.** *Lacerta.*
4. Class **Aves.** *Columba.*
5. Class **Mammalia.** *Lepus.*

PROTOZOA

ANIMAL MORPHOLOGY

PROTOZOA

Amoeba (Gk. *amoibe*, change).

1. Observe the animal alive in a drop of water on a microscope slide; sketch the animal to show changes of shape.

2. Cover with coverslip. By method of irrigation, first fix with $\frac{1}{4}$ per cent osmic acid and then stain with picro-carmine. **Draw** under high power: *pseudopodia*; *ectoplasm*; *endoplasm*; *nucleus*; *contractile vacuole*; *food vacuoles.*

Paramecium (Gk. *paramekos*, oblong).

1. Observe alive as for *Amoeba.*

2. Support a coverslip on pieces of broken glass over a drop of water containing *Paramecia.* Introduce at one side with a fine pipette a little $\frac{1}{50}$ per cent acetic acid; note the effect on the movements of the animals.

3. By method of irrigation, fix with $\frac{1}{4}$ per cent osmic acid and then stain with picro-carmine. **Draw** under high power: *cortical layer*; *cilia*; *trichocysts*, some of which may be discharged; *food vacuoles* (one of these may show position of *temporary anus*); *gullet*; *undulating membrane*; *micronucleus*; *meganucleus.*

4. **Draw** from various animals successive stages of the contractile vacuole. Look for any stages of fission or conjugation.

Vorticella.

1. Observe living animals adhering to solid material in a drop of water. Under low power, NOTE expansions and contractions of stalk.

2. By method of irrigation, fix with $\frac{1}{4}$ per cent osmic acid and then stain with picro-carmine. **Draw** under high power: *disc*; *peristome*; *cilia*: *vestibule*; *gullet*; *cortical layer*; *myonemes* (continuous with *fibres* of *stalk*); granular *endoplasm*; *food vacuoles*; *vacuole*; *nucleus.*

3. Look for any stages of binary fission, fission to form gametes, conjugation.

Polytoma.

1. Fix and stain by irrigation with iodine solution. **Draw** under high power: two *flagella*; two *contractile vacuoles*; *nucleus*; *starch grains*; *cuticle.*

2. Look for any stages of fission.

Trypanosoma (Gk. *trypanon*, borer; *soma*, body). From prepared slide of blood infected with this parasite, **draw** under high power: *flagellum* attached to *undulating membrane*; *nucleus.*

Monocystis (Gk. *monos*, single; *kyste*, bladder).

1. Remove part of the vesicula seminalis from an earthworm and tease out its

contents into physiological salt solution on a microscope slide. **Draw** mature animal: *cortex*; granular *endosarc*; *nucleus*. Look for any forms covered with spermatozoa tails.

2. **Draw** the following stages of development:

(*a*) Two individuals in *cyst*.
(*b*) Encysted individuals breaking up into *gametes*.
(*c*) Cyst containing *zygotes* (*sporonts*).
(*d*) Mature cyst with *pseudonavicellae*.

Plasmodium (Haemamoeba). From prepared slide of blood-smear of malarial patient, **draw** parasites with red blood corpuscles.

COELENTERATA

Hydra. Found attached to weeds in fresh-water ponds.

1. Observe animal alive under water in a watch-glass, NOTE animal expanded and contracted. **Draw**: *foot*; *body*; *tentacles*; *hypostome*; *mouth*; *bud*, *ovary*, and *testes*, if present.

2. Mount animal on slide in water and cover with supported coverslip.

(*a*) **Draw** tentacle under high power: *cnidoblasts* in clusters; *cnidocils*; *endoderm*.

(*b*) Add a little dilute acetic acid. **Draw** exploded *nematocysts*, some have *barbs* and may be completely ejected.

3. (*a*) **Draw** a plan from prepared slide of transverse section across animal under low power: *ectoderm*; *mesogloea*; *endoderm* (coloured green in *H. viridis*); *enteron*.

(*b*) **Draw** a detailed segment under high power: ectoderm with *musculo-epithelial* cells, smaller *interstitial* cells in clusters, *nematocysts*, *mesogloea*; endoderm with large vacuolate cells, green symbiotic algae in *H. viridis*.

4. **Draw** a plan from prepared slide of longitudinal section of animal under low power. NOTE that the tentacles are hollow.

Obelia. Marine colony resembling a knotted thread. It is very common on seaweed, particularly the ribbon seaweed (*Laminaria*). The colony is luminous at night. The animal may be killed with the polyps expanded by the following narcotics: 7 per cent magnesium chloride in tap water or 2 per cent magnesium sulphate in sea-water.

1. Stain a portion of the colony with borax carmine and make a permanent preparation, following carefully the directions on page 8.

2. From your prepared slide, **draw** under low power: *stolon*; *stalk*; *perisarc*; *coenosarc*; *ectoderm*; *endoderm*; *mesoglea*; *enteron*; *nutritive polyps* with *tentacles*, *mouth*, *hypostome*, and *hydrotheca*; *reproductive polyp* with *blastostyle*, developing *medusae* and *gonotheca*.

3. **Draw** medusa mounted in water under low power: *tentacles*; 5–8 *statocysts*; *ocelli*; *manubrium*; *mouth*; 4 *radial canals* with *gonads* situated under each; *circular canal*.

COELENTERATA

PLATYHELMINTHES

ANIMAL MORPHOLOGY

PLATYHELMINTHES

Fasciola (Distomum). The liver-fluke from bile-ducts of the sheep.

1. **Draw** animal as seen under hand-lens: *anterior sucker* with *mouth*; *ventral sucker*; *genital aperture.*

2. **Draw** from prepared slide under low power: *branched gut* leading to *pharynx* in *anterior sucker*; *testes*; *penis*; *ovary*; *oviduct*; *yolk glands*; *uterus*; *shell gland*; *genital aperture.*

3. **Draw** stages in life history from prepared slides:

(*a*) *Miracidium.*
(*b*) *Sporocyst* containing developing *rediae.*
(*c*) *Rediae* with *mouth, gut,* and contained *daughter rediae.*
(*d*) *Cercaria* with *oral* and *ventral suckers, branched gut, tail.*

Taenia (Gk. *tainia,* band). *T. serrata,* the tape-worm from alimentary canal of the dog.

1. **Draw** under hand-lens: *scolex*; *hooks*; *suckers*; *rostellum*; young *proglottides* at anterior end. NOTE large mature proglottides at posterior end.

2. **Draw** from prepared slide sexually mature proglottis under low power: *nerve cords*; *excretory canals*; *transverse canal*; *testes*; *vas deferens*; *ovaries*; *uterus*; *yolk glands*; *shell gland*; *vagina*; *genital aperture.*

3. **Draw** proglottis with developing embryos: enlarged *uterus* breaking up into capsules containing *eggs* and *embryos.*

4. **Draw** cysticercus or bladder-worm stage from liver of the rabbit: *bladder* filled with fluid; extruded *scolex* with *suckers* and *hooks.*

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Lumbricus (Lat. earthworm).

1. **Draw** ventral view of worm: first segment made up of *prostomium, peristomium*; *mouth*; *ventral* and *lateral setae*; *spermathecal pores* between segments 9–10 and 10–11; *female genital pores,* segment 14; *male genital pores* with swollen lips, segment 15; *clitellum,* segments 32 to 37 inclusive. NOTE dorso-ventrally flattened posterior region.

2. Remove a seta, mount in glycerine, and **draw** under low power.

3. Pin the animal with two pins through segment 5 and two near the hind end, *ventral side downwards,* in a dissecting dish and cover with water. Cut with fine scissors the body wall near the mid-dorsal line at segment 25, then cut forwards to segment 2. Pin down the cut surfaces to either side; place pins to mark definite segments (20, 15, 10, 5). NOTE: *coelom* and *transverse septa*; *pharynx* with *muscles*; *supra-pharyngeal ganglia* (segment 3); *oesophagus*; *oesophageal pouches* (segment 11); *oesophageal glands* (segment 12); *crop*; *gizzard*; *intestine* covered with *chloragogenous cells*; *vesiculae seminales* (segments 9 to 12); *spermathecae* (segments 9 and 10); *dorsal blood vessel*; *hearts* (segments 7 to 11). **Draw** a plan of the alimentary canal.

4. Cut through the septa and remove alimentary canal from front of pharynx to end of gizzard.

(*a*) **Draw** nervous system in segments 3 to 8: *supra-pharyngeal ganglia* (segment 3); *commissures*; *sub-pharyngeal ganglia* (segment 4); *ventral nerve cord* with *ganglia* and *nerves* in each segment.

(*b*) **Draw** genital and excretory organs in segments 9 to 15: *spermathecae* (segments 9 and 10); *vesicula seminalis* with two pairs *anterior* and one pair *posterior horns* (segments 9 to 12); *ovaries* attached to septum dividing segments 12 and 13; *oviducts* with *funnels*; *nephridia.*

(*c*) Remove wall of vesicula seminalis on one side and NOTE *sperm funnels* and *vas deferens.*

5. Remove an ovary. **Draw** under low power with developing *ova.*

6. Open a worm, which has been freshly killed with chloroform, under physiological salt solution.

(*a*) Remove nephridium and mount in salt solution. **Draw** under low power: *nephrostome*; *ciliated, glandular,* and *muscular* portions of *excretory tube*; *connective tissue* with *blood-vessels.*

(*b*) Remove a portion of vesicula seminalis, smear contents over a coverslip. Fix with 90 per cent alcohol, stain with borax carmine, dehydrate, and mount in Canada balsam. **Draw** stages of development of spermatozoa. Look for *Monocystis.*

7. **Draw** from prepared slide transverse section in region of intestine: *body wall* with *cuticle, epidermis, circular* and *longitudinal muscles*; *coelom*; *intestine* with *chloragogenous cells, circular* and *longitudinal muscles, endoderm, typhlosole, ventral nerve cord*; *dorsal blood-vessel*; *sub-intestinal blood-vessel*; *lateral* and *sub-neural blood-vessels*; *nephridia*; *lateral* and *ventral setae*; *dorsal pore.*

Nereis. The common rag-worm, found between tide-marks, and used for bait.

1. NOTE: body composed of 80–90 segments, each bearing a pair of *parapodia*; *blood-vessels* running down dorsal side and showing through the skin; *anal cirri.*

2. **Draw** dorsal view of head under hand-lens: *prostomium* with *eyes, tentacles* and *palps*; *tentacular cirri*; extruded *pharynx*; *peristomium*; segment 2 with *parapodia.*

3. Remove a parapodium, mount in glycerine, and **draw** under low power: *notopodium* with two *lobes* and *dorsal cirrus*; *neuropodium* with two *lobes* and *ventral cirrus*; *setae*; *acicula.*

ARTHROPODA (Crustacea)

Astacus. The English crayfish, *A. torrentium,* found in rivers, is a greenish colour and about three inches long; the continental form, *A. fluviatus,* is larger and has reddish legs and chelae. When 'in berry' the female carries the eggs on her abdominal appendages. Kill by immersion for a few minutes in boiling water.

1. (*a*) NOTE in dorsal view: *antennules* (*first antennae*); *second antennae*; *eyes*; *chelae*; *cephalothorax*; *rostrum*; *cervical groove*; *branchiostegite*; *branchiocardiac groove*; four pairs of *walking legs*; six segments of *abdomen*; *terga*; *pleura*; *telson.*

(*b*) NOTE in ventral view: *female aperture* on second walking leg; *male aperture*

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on fourth walking leg; *sterna*; uniramous *first abdominal appendage*, small in female, modified for transference of sperm in male; biramous *abdominal appendages* (segments 2–5); *endopodite* and *exopodite* of *sixth abdominal appendage* forming modified tail fan with the *telson*.

2. Cut away the branchiostegite on one side. NOTE: *gills* and *scaphognathite*.

3. Remove the first walking leg on one side and work forwards, removing one of each pair of mouth appendages in turn.

(*a*) **Draw** first walking leg: *endopodite*; *protopodite*; *basipodite*; *coxopodite* with *setae*; *epipodite*; *gill*.

(*b*) **Draw** third maxilliped: parts as for walking leg with *exopodite*. NOTE: same parts on second maxilliped and first maxilliped, the latter does not bear a gill.

(*c*) **Draw** second maxilla: *protopodite*; *endopodite*; *exopodite* and *epipodite* fused to form *scaphognathite*. NOTE: first maxilla (*maxillule*); *protopodite*; *endopodite*.

(*d*) **Draw** mandible: *coxopodite* with incisor edge; *basipodite* and *endopodite* forming *palp*.

(*e*) **Draw** second antenna: *coxopodite* with *renal aperture*; *basipodite*; *exopodite* (*scale*); *endopodite* (*flagellum*).

4. Remove carapace of a freshly killed crayfish just above the heart and inject carmine by means of a fine pipette through one of the ostia. Remove remaining dorsal portion of carapace and the abdominal terga. Dissect the animal under water. NOTE: *haemocoel*; *heart*; *ostia*; *ovary* or *testes* and *vas deferens*; *liver*; *proventriculus* with *muscles*; *hind gut*; *muscles* of *mandibles*; *flexor muscles* of *abdomen*; *dorsal abdominal, antennary, ophthalmic,* and *gastric arteries*.

5. Cut away the heart, then remove carefully the alimentary canal by cutting through oesophagus and rectum. **Draw**: *oesophagus*; *cardiac* and *pyloric* portions of *stomach*; *mesenteron* with *caecum* and *openings* of *bile ducts*; *hind gut*.

6. Remove gonads and ducts. NOTE in **male**: *anterior* and *posterior lobes* of *testes*; *vasa deferentia*. Examine contents of vas deferens, mounted in physiological salt solution, under the microscope. **Draw** *spermatozoa* with stiff processes. NOTE in **female**: *anterior* and *posterior lobes* of *ovary*; *oviducts*.

7. Remove internal skeleton of thorax and muscles in order to expose nervous system. Pour off the water from the thorax and make the nerve cord opaque by pouring in 90 per cent alcohol or picric acid. NOTE: *supra-oesophageal ganglion*; *transverse commissure*; *circum-oesophageal commissures*; *sub-oesophageal ganglion*; six *thoracic ganglia* connected by *ventral nerve cords*; *sternal artery* between fifth and sixth ganglia; six *abdominal ganglia* connected by *nerve cord*.

8. In front of mouth and in ventral position, NOTE *green glands* with *excretory ducts* leading to base of second antenna on each side.

9. **Draw** from prepared slides sections through eye and statocyst.

ARTHROPODA (Insecta)

Order **Orthoptera** (Gk. *orthos*, straight; *pteron*, wing). Neither the common cockroach, *Blatta orientalis* (Lat. cockroach from the East), nor the larger form, *Periplaneta* *americana* (Gk. *peri*, around; *planes*, wandering), are indigenous to England. They are nocturnal insects, omnivorous and fond of warmth, hence are common in kitchens and bake-houses. They should be killed with chloroform.

B. orientalis. Total length about one inch. Antennae as long as body. Male has elytra enclosing one pair of wings which are not quite as long as the body. Female has rudimentary wings and elytra reduced to lobes. Dark brown in colour.

P. americana. Total length 1½ inches. Antennae as long as body. Both sexes have elytra and fully developed wings which are longer than the body. Reddish-brown in colour.

1. (*a*) **Draw** dorsal view of *Periplaneta* with elytra and wings extended sideways: **head** with *compound eyes, antennae*; **thorax** with large *notum* of *prothorax* covering neck, *meso-* and *metathorax, elytra* attached to anterior end of *mesothorax, wings* with *nervures* attached to anterior end of *metathorax,* three pairs of *legs*; **abdomen** with ten jointed *terga,* eighth and ninth covered by the seventh, *podical plates, cerci anales, copulatory styles* in male.

(*b*) **Draw** ventral view of abdomen of male and female: **Male** with *sterna* of nine segments; *copulatory styles* attached to ninth sternum; *cerci anales* attached to tenth tergum; *podical plates* (remnant of eleventh tergum). **Female** with *sterna* of seven segments, the seventh making the floor of the *genital pouch*; *cerci anales* attached to tenth tergum; *podical plates* (remnant of eleventh tergum).

(*c*) **Draw** side view of head seen under hand-lens: *jointed antenna*; *compound eye*; *fenestra*; *gula*; *first* and *second maxillary palps*; *mandible*; *labrum.*

2. Remove a leg and **draw** under hand-lens: *coxa*; *trochanter*; *femur*; *tibia*; *tarsus* with *five segments* (four only if regeneration has taken place after injury); *claws.*

3. Remove the head by cutting through the neck. Boil the head in 1 per cent caustic potash in a test-tube to decompose the muscles. Place in a watch-glass and remove the mouth parts with forceps and needle; first remove labium, then first maxillae and mandibles. If the parts do not separate easily, return to the caustic potash and reboil. Dehydrate *thoroughly,* clear, and mount in Canada balsam; the coverslip should be supported on pieces of glass. **Draw** under low power: *second maxillae* (labium), fused *protopodites* made up of *mentum* and *submentum, endites* (ligula) made up of *lacinia* and *paraglossa, endopodite* a three-jointed *palp*; *first maxilla, protopodite* made up of *cardo* and *stipes, endites* made up of *galea* and *lacinia, endopodite* made up of a five-jointed *palp*; *mandible* with cutting edge (no palp).

For dissection of the cockroach, the insect should be held in melted wax in a tray with the terga just above the surface of the wax. On cooling, the wax will hold the insect firmly, and it should now be dissected under water.

4. Remove abdominal and thoracic terga carefully in order to see heart with ostia lying *in situ* in pericardium. Unravel the alimentary canal from surrounding fat bodies.

(*a*) **Draw**: *salivary gland* and *receptacle*; *oesophagus*; *crop*; *proventriculus*; *hepatic caeca*; *Malpighian tubes*; *ileum*; *colon*; *rectum.*

(*b*) Cut open the proventriculus to show the *cuticular teeth.*

5. Remove a portion of the tracheal system with fat bodies. Stain with picro-

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carmine and mount in water. **Draw** under low power: *tracheae* with cuticular thickening. Under high power look for nuclei of sheathing cells which secrete the chitinous lining.

6. Remove salivary gland, mount in water, and NOTE under high power the *ducts* and *receptacle.*

7. Remove alimentary canal and fat bodies in order to reveal generative organs.

(*a*) NOTE in **male**: *vesiculae seminales*; *ejaculatory duct*; *asymmetrical copulatory styles* (*gonapophyses*). **Female**: *ovaries*; *oviduct*; *spermatheca, colleterial glands*; *symmetrical copulatory styles.*

(*b*) Remove a portion of the ovarian tube, mount in glycerine, and **draw** under low power the ova in various stages of development.

8. **Draw** nervous system: *cerebral ganglia*; *commissures*; *sub-oesophageal ganglion*; ventral *nerve cord* with three *thoracic ganglia*; *abdominal ganglia* in first six abdominal segments.

Amongst the Orthoptera, metamorphosis is incomplete. The egg hatches into a wingless *larva* which turns into the *imago* after several moults.

To mount the smaller insects and their mouth parts. The smaller insects may be killed without injury by placing in a test-tube containing a little cotton-wool soaked in chloroform. To examine the mouth parts, the head is removed, boiled in caustic potash, dehydrated, cleared, and mounted in Canada balsam without further dissection. Berlese fluid (Appendix A) provides an excellent alternative clearing and mounting fluid either for the complete insect or head and mouth parts alone. When using this reagent, kill and fix by brief immersion in 10 per cent acetic acid in distilled water or by placing insect in boiling water. If in spirit, wash first with 10 per cent acetic acid. No dehydration is necessary before mounting in Berlese fluid. When the slide has been covered, warm gently and allow to dry and set at room temperature in one or two weeks. Ring the preparation with gold size or Brushing Belco.

Order **Diptera** (Gk. *di*, two; *pteron*).

Musca domestica (Lat. house fly). The common house fly is about $\frac{1}{4}$ inch long, is mouse-grey in colour, and has four narrow black stripes on the dorsal side of the thorax. There is a wide space between the eyes on the head as seen above in the female; in the male this space is narrower. The fourth longitudinal vein on each wing is elbowed in such a way that its end nearly meets that of the third longitudinal vein. NOTE: single pair of wings in the imago and the *halterers* or *balancers.*

1. Remove head and make permanent preparation so that the proboscis lies extended. **Draw**: *antennae*; *compound eyes*; *ocelli*; *palps* of *first maxillae* (the remainder of the maxillae and mandibles have disappeared); *proboscis* formed from *labrum* and *labium* (second maxillae), the latter terminating in broadened *labella* which are traversed by *pseudotracheae*; *hypopharynx.*

2. **Draw** stages in its life history: *eggs*; white legless **larva** with twelve segments tapering towards head, which has a pair of hook-like *mandibles* and two *antennae*, pair of *spiracles* on second and last segments; barrel-shaped *puparium* which is formed from hardened skin of larva and covers the **pupa** within (coarctate pupa). Within the pupa, the larval tissue breaks down and is built up again into the adult tissue

(*histolysis*). The puparium splits transversely to allow the imago to emerge. Metamorphosis is complete.

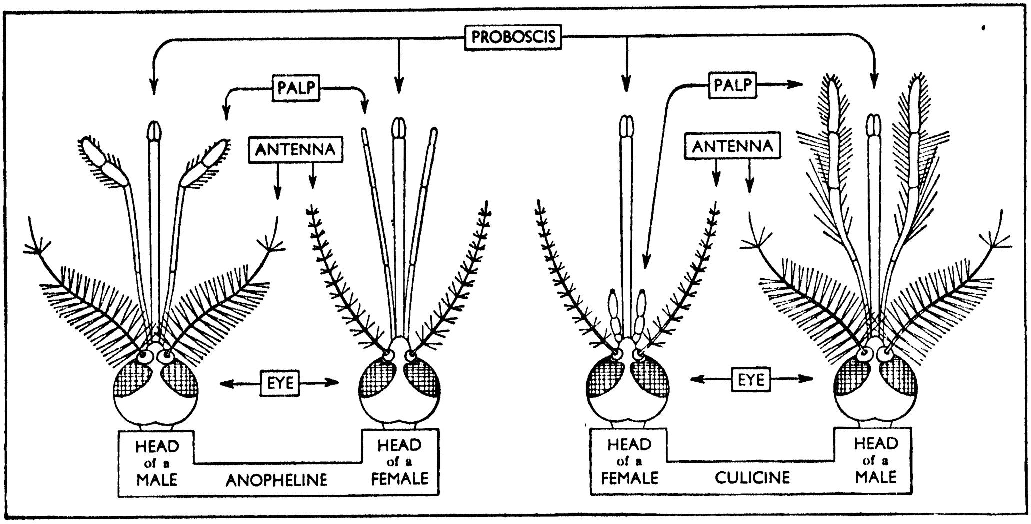
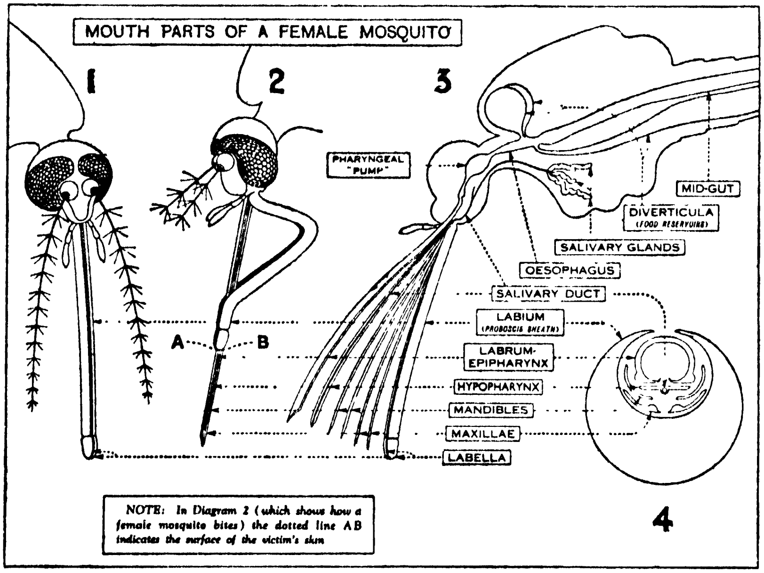


Fig. 30. The mouth parts of anophelene and culicine mosquitoes. The latter are termed gnats



NOTE: In Diagram 2 (which shows how a female mosquito bites) the dotted line AB indicates the surface of the victim's skin

Fig. 31. Mouth parts of a female mosquito
Showing the proboscis (1) at rest, (2) during the act of biting, (3) with the constituent parts separated and (4) in cross section. For the sake of clearness in diagram (3) the salivary glands of one side only are shown.

Anopheles (Gk. harmful). Mosquitoes are found all over the world, the total number of known species being over two thousand. They are divided into two great 'tribes',

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the Culicines and the Anophelines. In Great Britain there are three Anopheline and twenty-four Culicine species.

1. NOTE in *Anopheles*: *head* with bushy *antennae* in males, slender and thread-like in female; *palps* long and tufted in male, slender in female; *proboscis*; single pair of *wings*; *halterers*; *abdomen* with eight visible segments (ten in all) uniformly dark in colour.

2. Remove head and make permanent preparation with mouth parts lying extended and separated. **Draw**: *compound eyes*; *antennae*; *labrum* (*epipharynx*); *labium* (proboscis sheath) terminating in *labellae*; two *mandibular styles*; two *palps* and *styles* of *first maxillae*; *hypopharynx* with salivary duct.

3. **Draw** stages in life history:

(*a*) **larva**; *mouth brushes*; *palmate hairs* on abdomen for suspension from surface film of water; *spiracles* on eighth abdominal segment; *hooked hairs* on ninth abdominal segment. The larva lies horizontally when breathing, the spiracles breaking through the surface film of water. The mouth brushes set up currents which wash food into the mouth.

(*b*) **pupa** formed after four moults (*ecdysis*); enlarged *thorax*, two *respiratory trumpets*; small *abdomen* with two *paddles*. The pupa is obtect and metamorphosis is complete.

Order **Lepidoptera** (Gk. *lepis*, scale; *pteron*).

1. NOTE in cabbage white butterfly (*Pieris brassicae*): *head* with *compound eyes* and knob-ended *antennae*; coiled *proboscis*; two pairs of *wings*; *thorax*; three pairs of *legs*; *abdomen*.

2. Remove a portion of the wing, mount in water, and under magnification NOTE the *scales*.

3. Remove head and make permanent preparation with proboscis lying extended. **Draw**: *compound eyes*; *antennae*; *proboscis* formed from galeae of first maxillae, each bearing a small *palp*; *labial palps*; *pilifers* of labrum.

4. **Draw** stages in life history:

(*a*) (i) **larva** (caterpillar); *head* with six simple eyes (*ocelli*); on each side *thorax* with three segments each bearing a pair of *legs*; first two abdominal segments without legs, segments 3–6 with *prolegs*; one pair of *spiracles* on side of first thoracic segment, eight pairs on abdominal segments.

(ii) Remove the head and make permanent preparation. **Draw**: *ocelli*; *labrum*; *antennae*; *mandibles*; *first maxillae* and *palps*; *labium* with *spinneret* through which is the opening to the salivary duct.

(*b*) **pupa** (chrysalis); *eyes*; *antennae*; *wings*; *abdominal segments* with *spiracles*. The wings can be seen stuck down to the hardened integument of the pupa (obtect pupa). Metamorphosis is complete.

Order **Hymenoptera** (Gk. *hymen*, membrane; *pteron*).

1. NOTE in *Apis mellifica*, the honey bee:

(*a*) sterile female (worker); *head* with *compound* and *simple eyes*; *antennae*;

thorax with two pairs of *wings* and three pairs of *legs* bearing *pollen-baskets*; *abdomen* with six segments visible, *anus*, and *sting*.

(*b*) male (drone); same parts as in worker; pollen-baskets and sting absent.

(*c*) fertile female (queen); long *abdomen* with *sting*; pollen-baskets absent.

2. Remove the two wings of one side, NOTE *sensory hairs* and the *wing-coupling apparatus* which consists of a series of hooks.

3. Remove head and make permanent preparation with mouth parts extended and separated. **Draw**: *compound* and *simple eyes*; *antennae*; *labrum*; *mandibles*; *galeae* of first maxillae each with *palp*; *paraglossae*; *labium* with *palps* and *ligula*.

4. (*a*) **Draw** first leg: *tarsus* with hairs forming collecting brush; antenna-cleaner on *tibia*; *femur* with long hairs.

(*b*) **Draw** third leg: pollen-collecting hairs on *tibia*; pollen-combs on *tarsus*.

5. **Draw** stages in life history:

(*a*) **larva**; *head*; similar *thoracic* and *abdominal segments*; *spiracles*. NOTE absence of legs.

(*b*) **pupa**; *head* with *eyes* and *antennae*; *thorax* with rudimentary *wings* and *legs*; *abdomen*.

The wings and legs are free and are not stuck down to the body of the pupa (exarate pupa). Metamorphosis is complete.

ARTHROPODA (Arachnida)

1. **Draw** spider (order *Araneida*) in dorsal view: *chelicerae*; *pedipalpi*; *eyes*; four pairs of *legs* attached to *prosoma*; unsegmented *opisthosoma* attached to prosoma by narrow ‘ waist ’.

2. Remove front part of prosoma with mouth parts, boil in caustic potash, and mount. **Draw**: *eyes*; *pedipalpi* with *gnathobases* and *palpal organs*; *chelicerae* with *claws*.

MOLLUSCA (Gastropoda)

Helix (Gk. spiral). The Roman snail, *H. pomatia*, is better for dissection than the smaller garden snail *H. aspersa*. In order to kill snails in an expanded condition, place in a gas-jar filled with distilled water and cover with a coverslip so as to exclude all air. When killed immerse snails in 50 per cent alcohol to remove the mucus.

1. NOTE movements of live snail by allowing the animal to crawl over glass plate, inverting and watching under surface.

2. **Draw** entire animal from right side: *shell*; *head* with *eye-tentacles* and *anterior tentacles*; *mouth*; *foot*; *reproductive aperture*; *edge of mantle*; *anus*; *respiratory pore*. Pass seeker into aperture of pedal mucus gland which lies between mouth and foot.

3. Pin down the snail under water and remove the shell. Cut along the line joining the mantle to the body so as to expose the respiratory chamber. Cut round the outer wall of the visceral hump and below the anus and rectum so that they come away with the roof of the respiratory chamber. NOTE: floor of *respiratory chamber*; *heart* with *auricle* and *ventricle* lying in *pericardium*; *kidney* with *ureter*; *upper wall* of *respiratory chamber* with *blood-vessels*. Open pericardium and pass bristle into opening to kidney.

MOLLUSCA

ECHINODERMATA

4. Make a median cut through the dorsal wall of the body, passing through the cut surface of the mantle cavity to the head. Separate the digestive organs and pin out to the left-hand side; unravel the generative organs from the visceral hump and pin out to the right-hand side.

(*a*) NOTE: *pharynx*; *nerve-collar*; two *salivary glands* with *ducts*; *oesophagus*; *stomach*; *liver*; *intestine*; *rectum*; *muscles*. Make a plan of the digestive organs.

(*b*) NOTE: *hermaphrodite gland* in apex of shell; *hermaphrodite duct*; *male duct* with *flagellum*; *penis*; *albumen gland*; *female duct*; *spermatheca* with *duct* and *flagellum*; *mucus glands*; *dart sac*; *vagina*. Make a plan of the reproductive organs.

5. Remove radula from buccal mass, mount in glycerine, and observe under magnification.

MOLLUSCA (Lamellibranchiata)

Anodon (Gk. *anodous*, toothless). The fresh-water mussel may be found buried in the mud at the bottom of streams and lakes.

1. **Draw** side view of animal. *boss* at apex of shell (*umbo*); position of *hinge* on dorsal surface; *lines* of *growth* on shell; *foot* at anterior end.

2. Remove left valve of shell by cutting through muscles and separating the mantle. **Draw** animal lying in right valve of shell: *foot*; cut surfaces of two *abductor*, two *retractor* and *protractor muscles*; *dorsal* (exhalant) and *ventral* (inhalant) *siphons*; *lobe of left mantle*; *edge of right mantle*.

3. Place the animal under water and turn back the left mantle lobe. NOTE: *labial palps*; position of *mouth*; *foot*; *line of attachment of outer gills* with *mantle*.

4. Pin back the labial palps of the left side and cut through attachment of anterior portion of inner gill lamella to foot. NOTE: left *kidney* and *genital openings*; *line of attachment of posterior portions of left* and *right inner gill lamellae*.

5. Remove a portion of gill lamella, mount in water, and observe under low power the gill filaments with supporting chitinous rods and ciliated epithelium.

6. Remove dorsal wall of body to expose the pericardium. NOTE: *rectum* surrounded by *ventricle*; *auricles*; *reno-pericardial openings* on floor of pericardium at anterior end.

7. **Draw** from prepared slides of transverse sections through animal in following regions: (*a*) middle of foot, (*b*) hinder part of foot, (*c*) behind the foot; *mantle lobes*; *gill lamellae*; *epibranchial spaces*; *pericardium*; *auricles*; *ventricle*; *rectum*; *vena cava*; *kidney* (glandular and non-glandular portions); *foot* containing *gonads* and *intestine*.

8. Examine and draw prepared slide of the *glochidium larva*.

ECHINODERMATA

This phylum is entirely marine and its members are found at all depths of the sea. *Asterias rubens*, the common starfish, occurs between tide-marks; it is usually reddish-orange or yellow; a smaller variety found in deeper water is violet in colour.

1. NOTE method of moving and action of tube-feet in live specimen and then kill by immersion in warm fresh water.

2. (*a*) **Draw** a plan of animal from oral surface: *mouth*; five *arms*; *ambulacral grooves* with four rows of *tube-feet*; *ambulacral spines*; *ocelli.*

(*b*) NOTE on aboral surface: *madreporic plate*; *spines*; *branchiae*; *pedicellariae* on spines, between spines, and on bases of blunt spines.

3. Remove a small pedicellaria from base of blunt spine and a larger form from interspace between spines, mount, and observe under low power; the larger kind have blades which do not cross; the blades of the smaller kind cross.

4. Cut along both sides of each arm with scissors and raise the upper half of the animal, removing with it the gonads and alimentary canal. Cut through the oesophagus, stone canal, and muscles.

(*a*) **Draw** plan of aboral portion: *stomach*; *pyloric sac*; *pyloric ducts* dividing in each arm into two *pyloric caeca*; *rectum* with *rectal caeca* leading from pyloric sac to aboral surface; *gonads.*

(*b*) **Draw** plan of oral portion: *stone-canal*; position of *water-vascular ring*; *Tiedmann's bodies*; *ambulacral ridges*; *ampullae* of *tube-feet.*

5. **Draw** plan of transverse section of arm from prepared slide: *ectoderm*; *ambulacral spines*; *branchiae*; *pedicellariae*; *dermal ossicles*; *coelom*; *pyloric caeca*; *ambulacral ossicles*; *ampullae*; *tube-feet*; *radial water-vessel*; *perihaemal spaces* divided by *septum*; *radial nerve cord.*

CHORDATA (Cephalochorda)

Amphioxus (Gk. pointed at both ends), also known as the lancelet. Found in the sea; it burrows into the sand and lies hidden with its mouth projecting just above the surface. When living it is semi-transparent.

1. **Draw** whole animal from left side: *mouth* with *cirri*; *dorsal, caudal,* and *anal fins*; *anus*; *atrial pore*; *myotomes*; *gonads* seen through transparent wall of atrium.

2. **Draw** from prepared slide of transverse section through region of pharynx: *fin ray*; *nerve cord*; *notochord* (always ventral side of nerve cord); *myotomes*; *metapleural folds*; *atrium*; *pharynx* with *gill-slits*; *endostyle*; *dorsal groove*; *dorsal aortae*; *liver* on right-hand side; *gonads*; *coelom.*

CHORDATA (Vertebrata)

PISCES

Scyllium. The common dogfish, *S. canicula*, occurs on our coasts; the eggs are laid one or two at a time and have a horny case with long threads at the corners by which they are attached to seaweeds.

1. (*a*) **Draw** side view: *head*; *trunk*; *eye*; movable *lower eyelid*; *spiracle*; five *gill-slits*; *lateral line*; *dorsal, caudal,* and *anal fins* (median); *pectoral* and *pelvic fins* (paired).

(*b*) NOTE in ventral view: *nostrils*; *oro-nasal grooves*; *mouth*; *cloaca*; modified pelvic fins forming *claspers* in male.

(*c*) Examine placoid scales under magnification.

2. (*a*) Open abdominal cavity from ventral side. NOTE: *falciform ligament*; *bilobed*

CHORDATA

liver; *gall bladder*; *bile duct*; *cardiac* and *pyloric portions* of *stomach*; *duodenum*; *intestine*; *pancreas* and *duct*; *rectum*; *rectal gland*; *spleen*. **Draw** plan of alimentary canal.

(*b*) Open intestine to show spiral valve.

(*c*) Turn liver forwards. NOTE: *coeliac, anterior mesenteric*, and *lieno-gastric arteries*; *portal vein*.

3. Remove alimentary canal and slit open cloaca. **Draw** reproductive organs: **Male**: *testes*; *vasa efferentia*; *vas deferens* (Wolffian duct); *vesicula seminalis*; *sperm sac*; *cloaca*; *anus*; *claspers*; *mesonephros*; *excretory portion* of mesonephros with *ducts* opening into *urino-genital papilla*; *rudimentary opening to oviduct*. **Female**: *ovary*; *oviducts* (Müllerian ducts) with *internal opening*; *shell glands*; *cloacal opening*; *anus*; *vestigial* and *excretory portions* of *mesonephros*; *excretory ducts* opening into two *urinary sinuses* (Wolffian ducts); *urinary papilla*.

4. (*a*) Open pericardium. NOTE: *heart*; *ventricle*; *conus arteriosus*; *auricle*; *sinus venosus*; *ductus Cuvieri*; *hepatic, anterior* and *posterior cardinal sinuses*.

(*b*) Pass seeker into pericardio-peritoneal opening which lies under the heart.

5. Remove flesh behind the mouth to reveal thyroid gland, carry dissection back towards heart to show ventral aorta and afferent branchial arteries. **Draw** plan of one side: *ventral aorta*; five *afferent branchial arteries*; five *gill-clefts*; *visceral arches* and *gills*.

6. Cut through lower jaw and branchial arches on one side, turn floor of mouth outwards. Remove *carefully* mucous membrane from roof of the mouth in order to reveal the efferent branchial vessels which lie just underneath. **Draw** plan of one side: *dorsal aorta*; four *efferent branchial arteries*; *common, external, posterior*, and *internal carotid arteries*; *hyoidean artery*; *subclavian* and *coeliac arteries*; *gill-clefts* and *gills*.

7. (*a*) Remove skin from cranium and from around one eye. Pull eyeball outwards. NOTE in dorsal view: blood-clots in *orbital sinus*; *eyeball*; *superior oblique muscle*; *internal, superior*, and *external recti muscles*; nerves ii (*optic*) and iv (*pathetic*).

(*b*) Remove eye by cutting through the six muscles and optic nerve close to the eyeball. **Draw** plan of orbit in lateral view: muscles and nerves as in 7 (*a*); nerve iii (*oculomotor*) serving inferior oblique and all recti muscles except posterior; nerve iv, serving superior oblique muscle; nerve v (*trigeminal*), with *maxillary, mandibular*, and *ophthalmic branches*; nerve vi (*abducent*), serving external rectus muscle; nerve vii (*facial*), with *hyomandibular, palatine*, and *ophthalmic branches*.

8. (*a*) Expose the brain by cutting away the cartilage on the dorsal side of the cranium. NOTE: *olfactory lobes*; *cerebrum*; *thalamencephalon*; *optic lobes*; *cerebellum*; *restiform tracts*; *medulla oblongata*; *fourth ventricle*; *spinal cord*; *roots of cranial nerves* i–x, excluding vi.

(*b*) Cut away the cartilage from dorsal side of the auditory capsule until nerves ix (*glossopharyngeal*) and x (*vagus*) are exposed. Slit open anterior cardinal sinus and trace course of these nerves. NOTE: *semicircular canals*; *root* of ix and *branches* to *hyoid* and *first branchial arches*; *roots* of x and *branches* to *branchial arches* 2–5, *lateral line, heart*, and *viscera*.

9. (*a*) Remove brain by cutting through cranial nerves and spinal cord. **Draw** dorsal view, parts as in 8 (*a*).

(*b*) **Draw** ventral view: *olfactory lobes*; *cerebrum*; *optic chiasma*; *infundibulum*;

pituitary body; *medulla oblongata*; *restiform tracts*; *roots* of *cranial nerves* iii, v, vi, vii, viii, ix, and x.

10. (*a*) **Draw cranium** [1] in lateral view: *nasal capsule* and *rostrum*; *orbit of eye* with *foramina* for *nerves* ii, iii, iv, v, vi, and vii, *foramina* for *external carotid* and *hyoidean arteries*; *auditory capsule.*

(*b*) **Draw** dorsal view: *ethmoidal, orbital,* and *occipital regions*; *nasal* and *auditory capsules*; *fontanelle*; opening of tube to inner ear; *foramen magnum*; *occipital condyles.*

(*c*) NOTE ventral view: *facet* for *hyomandibula*; *foramina* for *internal carotid, external carotid arteries,* and *nerves* ix and x; *groove* for *carotid artery.*

11. **Draw jaws** and **branchial arches** in ventral view: *palato-pterygo-quadrate bar*; *Meckel's cartilage*; *hyomandibula*; *ceratohyal*; *basihyal*; *branchial arches* 1–5 made up of *epibranchials, ceratobranchials,* and *basibranchials.*

12. (*a*) **Draw pectoral girdle** in ventral view: *coracoid region*; *scapula*; *glenoid surface*; *propterygium*; *mesopterygium*; *metapterygium*; *cartilaginous* and *horny rays.*

(*b*) **Draw pelvic girdle**: *ischio-pubic region*; *acetabular surface*; *basipterygium*; *cartilaginous* and *horny rays*; *skeleton* of *claspers* in male.

13. (*a*) **Draw** side view of **vertebral column** in region of trunk: *centrum*; *neural arch*; *neural spine*; *intercalary plate*; *ventrilateral process*; *rib*; *foramina* for *dorsal* and *ventral roots* of *spinal nerves.*

(*b*) NOTE vertebral column in region of tail: *haemal arch* and *spine.*

14. **Draw** plan of transverse section across body behind pelvic girdle: *skin*; *myomeres*; *lateral line canal*; *neural arch*; *neural spine*; *nerve cord*; *notochord*; *centrum*; *caudal artery* and *vein.*

15. (*a*) Compare external features of skate. NOTE: developed *pectoral fins*; large *spiracles* and *spines* on dorsal surface; *gill-slits* and *cloacal opening* on ventral surface.

(*b*) External features of whiting or cod. NOTE: terminal *mouth*; *operculum*; anterior position of *pelvic fins*; *homocercal tail*; *lateral line*; *anus*; *urino-genital aperture.* Remove a scale and NOTE rings of growth under magnification.

AMPHIBIA

Rana (Lat. frog). *R. temporaria* is the common British species. Frogs may be easily killed by placing in an enclosed space with a little chloroform.

1. Sketch the animal in lateral view: *head*; *external nares* (nostrils); *mouth*; *eye*; *eyelids* (*upper* and *nictitating*); *tympanic membrane*; *trunk*; *fore limb* with *manus*; *sacral prominence*; *hind limb* with *pes*; *cloacal opening.*

2. (*a*) **Draw** palmar side of manus: four *digits* (2, 3, 4, 5), the *pre-axial* (2) enlarged and forming breeding-pad in male.

(*b*) **Draw** plantar side of pes: five *digits* (1, 2, 3, 4, 5); *web.*

3. (*a*) **Draw** inside view of mouth when fully opened: homodont *teeth* on top jaw; *vomerine teeth*; *internal openings* of *nares*; position of eyeballs; *openings* of *Eustachian tubes*; *oesophageal opening*; *glottis*; *tongue.*

(*b*) NOTE attachment of tongue; pass a bristle through the tympanic membrane on one side and into the mouth through the Eustachian tube.

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[1] The cartilaginous skeleton of the dogfish should be kept in weak alcohol and not be allowed to dry.

CHORDATA

4. Place the frog on its back under water in a dissecting-dish; extend the arms and legs and hold down by pins placed through the hands and feet. Deflect the skin from the muscular body wall and pin out to either side. NOTE: *lymph spaces*; *musculo-cutaneous blood-vessels*; *xiphoid cartilage*; *anterior abdominal vein* showing through muscular body wall; *hypoglossal nerves.*

5. (*a*) Make an incision in the muscular body wall on either side of the anterior abdominal vein. Pass a doubled piece of cotton through the slits and under the vein; now divide the threads and tie them so as to ligature the vein in two places (Fig. 32). Cut across the vein between the two ligatures.

(*b*) Remove the cut portions of skin. Open the muscular body wall by a longitudinal cut made a little to one side of the mid-dorsal line. Cut through the pectoral girdle, using a strong pair of scissors. Pin back the cut surfaces of the muscular body wall and stretch out the arms by moving the pins which pierce the hands. NOTE: *coelom*; *heart* lying in *pericardium*; *trilobed liver*; *gall bladder*; *lungs*; *stomach*; *duodenum*; *ileum*; *rectum*; *pancreas*; *bladder*; *mesentery*; *spleen*; *fat bodies*; mesonephric *kidneys*; *ovaries* or *testes*; *oviducts* in female; *hepatico-pancreatic duct*; *inferior vena cava*; *anterior abdominal vein.*

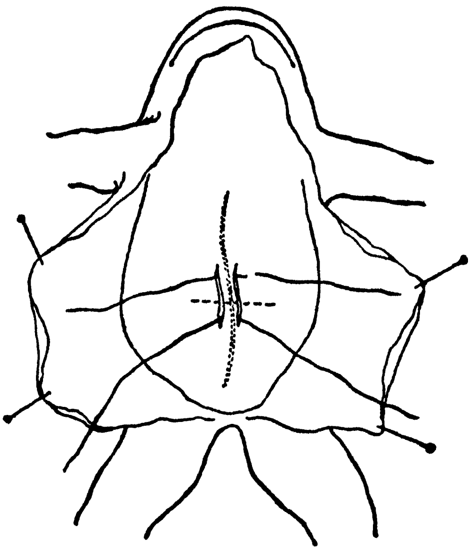


Fig. 32. Ligature of anterior abdominal vein of the frog.—The two ends of the top piece of cotton are tied, then the two ends of the lower, and a cut made in the direction of the horizontal dotted line

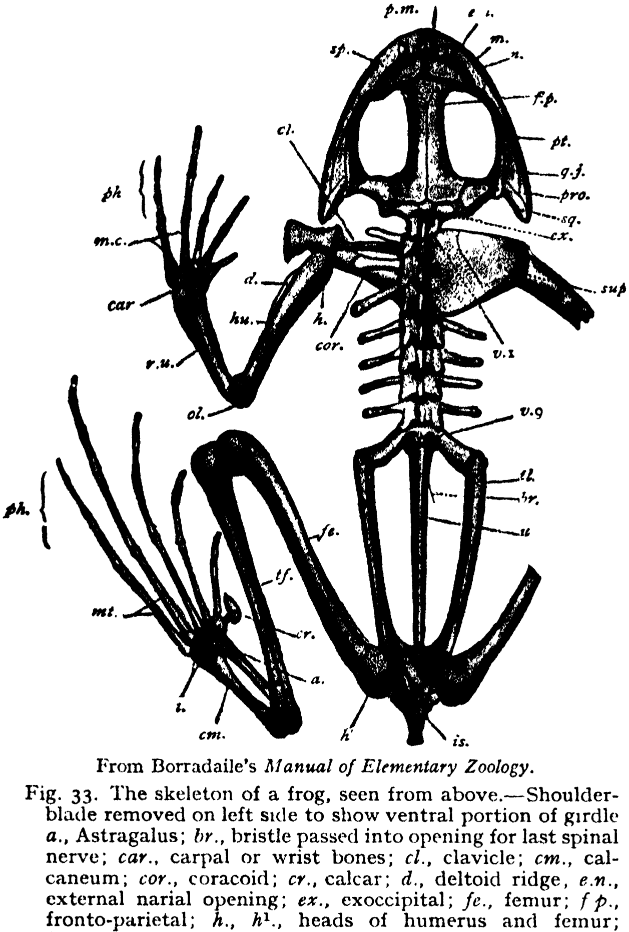
6. Remove alimentary canal from oesophagus to rectum and **draw.**

7. **Draw** reproductive organs: **Male**: *testes*; *vasa efferentia*; *urino-genital ducts* (Wolffian ducts); *vesiculae seminales.* **Female**: *ovaries*; *oviducts* (Müllerian ducts); *internal opening* of oviduct; *excretory ducts* (Wolffian ducts). In both sexes: *fat bodies*; mesonephric *kidneys*; *adrenal bodies*; *bladder*; *inferior vena cava*; *renal portal, femoral, pelvic, sciatic,* and *anterior abdominal veins.*

8. Deflect the cut surfaces of the pectoral girdle and stretch the limbs sideways. Remove the heart from the pericardium by cutting through the ligament which connects the ventricle with the dorsal wall of the pericardium. NOTE pulsations of heart if still beating.

(*a*) Turn heart forwards so as to expose dorsal side. Trace out course of veins which converge on heart and **draw** a plan: *sinus venosus*; *inferior vena cava*; *hepatic*; *renal*; *superior venae cavae*; *external jugular*; *lingual*; *mandibular*; *innominate*; *internal jugular*; *subscapular*; *subclavian*; *brachial*; *musculo-cutaneous*; *pulmonary.* Put in plan veins from Dissection 7.

(*b*) Cut through superior vena cava on one side, change the water and wash thoroughly. Trace out course of arteries with heart in normal position and **draw** a plan: *ventricle*; *auricles*; *conus arteriosus*; *pulmo-cutaneous arch*; *carotid arch* dividing into *lingual* and *common carotid*; *systemic arch*; *subclavian*; *coeliaco-mesenteric*; *dorsal aorta*; *renal*; *iliac*; *thyroid gland*.



From Borradaile's *Manual of Elementary Zoology*.

Fig. 33. The skeleton of a frog, seen from above.—Shoulder-blade removed on left side to show ventral portion of girdle *a.*, Astragalus; *br.*, bristle passed into opening for last spinal nerve; *car.*, carpal or wrist bones; *cl.*, clavicle; *cm.*, calcaneum; *cor.*, coracoid; *cr.*, calcar; *d.*, deltoid ridge, *e.n.*, external narial opening; *ex.*, exoccipital; *fe.*, femur; *f p.*, fronto-parietal; *h.*, h^1., heads of humerus and femur; *hu.*, humerus; *il.*, ilium; *is.*, ischium; *m.*, maxilla; *m.c.*, metacarpals; *mt.*, metatarsals; *n.*, nasal bone; *ol*, olecranon process; *ph.*, phalanges; *p m.*, premaxilla; *pro*, prootic; *pt.*, pterygoid; *q j*, quadratojugal; *r.u.*, radioulna; *sp.*, sphenethmoid; *sq.*, squamosal; *sup.*, suprascapula; *t.*, distal tarsals; *tf.*, tibiofibula; *u.*, urostyle; *v.1*, first or atlas vertebra; v.9, ninth or sacral vertebra. The dotted regions consist of cartilage.

9. Remove kidneys and generative organs. NOTE: *vertebral column*; *calcareous concretions*; *dorsal aorta*. **Draw** plan of spinal nerves: *hypoglossal* (i); *brachial plexus* (ii with branches from i and iii); *brachial nerve*; nerves iii, iv, v, vi; nerves vii, viii, ix, and x joining to form *sciatic plexus*; *sciatic nerve*; *ganglia* and *commissures* of *sympathetic nerves*; *rami communicantes*.

10. (*a*) Remove roof of skull and **draw** dorsal view of brain: *olfactory lobes*; *cerebral hemispheres*; *pineal stalk*; *optic lobes*; *thalamencephalon*; *cerebellum*; *medulla oblongata*.

(*b*) **Draw** ventral view of brain, removed from skull: *olfactory lobes*; *cerebral hemispheres*; *optic chiasma*; *infundibulum*; *pituitary body*; *crura cerebri*.

(The skeleton may be prepared by boiling the body in water and leaving the flesh to rot. Scrape off the flesh and clean the bones by brushing with a stiff brush; leave to bleach in sunlight.)

11. (*a*) **Draw skull** [1] in dorsal view: *premaxillae*; *maxillae*; *quadrato-jugals*; *squamosals*; *nasals*; *sphenethmoid*; *fronto-parietals*; *exoccipitals*; *pterygoids*; *prootics*.

(*b*) **Draw skull** in ventral view: *premaxillae*; *maxillae*; *vomers*; *teeth*; *palatines*; *pterygoids*; *sphenethmoid*; *parasphenoid*; *quadrato-jugals*; *prootics*; *exoccipitals* and *condyles*; *foramina* for nerves ii, v, vi, vii, ix, and x.

(*c*) **Draw** hyoid cartilage: *body* with *anterior* and *posterior horns*.

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[1] The student is advised before taking the frog's skull to study the skull of the turtle (page 113), which provides an excellent prototype for vertebrates.

CHORDATA

12. NOTE **vertebral column** in dorsal view: *atlas vertebra*; *presacral vertebrae* with *transverse processes*; *sacral vertebra*; *urostyle*; *ilium*; *ischium*; *acetabulum*. (The attachment of the pelvic girdle is pre-acetabular.)

13. (*a*) **Draw pectoral girdle** in ventral view and **fore limb**: *episternum*; *omosternum*; *xiphisternum*; *xiphoid cartilage*; *clavicle*; *coracoid*; *scapula*; *glenoid cavity*; *suprascapula*; *humerus*; *radio-ulna*; *carpals*; *metacarpals*; *phalanges* of digits (2–5).

(*b*) **Draw pelvic girdle** and **hind limb** in side view: *ilium*; *ischium*; *pubis*; *pubic symphysis*; *femur*; *tibio-fibula*; *astragalus*; *calcaneum*; *distal tarsals*; *metatarsals*; *phalanges* of digits (1–5).

Histology.

1. *Frog's Blood.* Smear a small drop of blood over a coverslip and mount in physiological salt solution. **Draw** under high power: *red blood corpuscles* in side and surface view with *nuclei*; *white corpuscles* (*leucocytes*) with *nuclei*.

2. *Mammalian Blood.* Mount a drop of human blood as for 1. **Draw** under high power: *red* and *white corpuscles*, white corpuscles only are nucleated.

3. *Dried and Stained Blood Film.* Smear fresh blood over clean, dry coverslip. Dry by waving in the air, then fix by immersion in 90 per cent alcohol and dry by exposure to the air. Immerse in Ehrlich's haematoxylin to stain, wash with tap water to remove all traces of stain. Counter-stain by immersion in eosin dissolved in 70 per cent alcohol, wash with 70 per cent alcohol, dehydrate, and mount in Canada balsam.

4. *Pigment Cells.* Take a small piece of the web from the toes of the frog and spread out in water on a slide. **Draw** under high power: *pigment cells*, some with pigment contracted, others with pigment extended into the processes.

5. *Adipose Tissue.* **Draw** under high power stained preparation of fat-body of frog: *fatty cells* with *nuclei* and large *fat-globules*.

6. *Hyaline Cartilage.* Remove a little of the edge of the xiphisternum of the frog, scrape clean and mount in salt solution. Irrigate with 1 per cent acetic acid. **Draw** under high power: *matrix*; *cartilage cells* with *nuclei*.

7. *Bone.* **Draw** under high power prepared section of bone: *Haversian canals*; *matrix* divided up into concentric layers (*lamellae*); spaces for protoplasm of bone cells (*lacunae*); spaces for cell processes (*canaliculi*).

8. *Striated Muscle.* Tease out a small piece of leg-muscle from the frog in salt solution. Cover and irrigate with 1 per cent acetic acid. **Draw** under high power: *fibres*; *muscle sheath*; *cross-striations*; *oval nuclei*; *nerve endings*.

9. *Nervous Tissue.*

(*a*) Remove a portion of the sciatic nerve of the frog, fray out with needles and mount in salt solution. Irrigate with $\frac{1}{4}$ per cent osmic acid and then with salt solution. **Draw** under high power: *nerve fibres*; *nodes of Ranvier*; *axis cylinder*; *neurilemma* with *nuclei*; *medullary sheath*.

(*b*) **Draw** under low power prepared transverse section of sciatic nerve of frog: *bundles* of *fibres*; *perineurium*; *artery* and *vein*.

(*c*) **Draw** under low power prepared transverse section of spinal cord of frog: *central* *canal*; *dorsal* and *ventral fissures*; *grey matter*; *white matter*; *dorsal* and *ventral horns*; large *nerve cells.*

10. **Draw** under low power preparation of transverse section through **ileum** of frog: *peritoneal epithelium*; narrow band of *longitudinal muscle fibres*; broader band of *circular muscle fibres*; *connective tissue* with *blood-vessels* and *lymph spaces*; *columnar epithelial cells* with *goblet cells.*

11. **Draw** under low power prepared section of **liver** of frog: *gland cells* with *nuclei*; *blood-vessels.*

12. (*a*) **Draw** under high power prepared section of **testis** of frog: *seminiferous tubule*; *connective tissue* with *blood-vessels*; *epithelial cells* forming *sperm-mother cells*; *bundle* of developing *spermatozoa.*

(*b*) **Draw** under high power prepared section of **ovary** of frog: *germinal epithelium*; *ova* with *nuclei* and *yolk-granules.*

Development of the Frog. Obtain some frog-spawn in spring and keep in fresh water in a large vessel with water weeds. Preserve the various stages of development in formal alcohol.

1. NOTE stages in segmentation of the egg.

(*a*) Fertilized *ovum* with black pigmented *upper pole* and white *lower pole.*

(*b*) *Cleavage furrows* in two, four, and eight-cell stages.

(*c*) **Draw** prepared section of *blastula* showing small *upper cells,* large *lower cells* with *yolk granules, nuclei,* and *blastocoel.*

2. (*a*) NOTE *gastrula* with *ectoderm, neural folds, yolk plug,* and *blastopore.*

(*b*) **Draw** prepared section of gastrula: *ectoderm*; large and small *endoderm cells*; *primitive gut*; remnant of *blastocoel*; *yolk plug.*

3. **Draw** lateral view of *larva* just after hatching: *head*; *eye*; *mouth* with *horny jaws*; *nares*; *cement gland*; *gills*; *anus.*

4. **Draw** later stages in the development of the larva (tadpole), showing growth of *operculum,* development of *hind* and *fore limbs,* and atrophy of the *tail.*

REPTILIA

Lacerta (Lat. lizard). NOTE external features: *head*; *neck*; *body*; rounded *tail*; *limbs,* each terminating in five *digits*; *eye* with three *lids*; *nares*; *tympanic membrane* in pit; *scales*; transverse *cloacal aperture.* For dissection of the lizard proceed as for the frog (pages 105–9).

Skull of turtle. Examine a turtle's skull with the aid of Fig. 34. NOTE: the relative positions of the bones; the absence of teeth and of any vacuities in the temporal region; the single occipital condyle.

AVES

Columba (Lat. pigeon).

1. NOTE external features: *head*; *neck*; boat-shaped *body*; *tail*; *beak*; *cere*; *nares*; *eye* with three *lids*; *ear*; *papilla* of *oil gland*; *cloacal aperture*; *wings* and *legs.*

2. NOTE **feathers.**

(*a*) *Quill feather* from wing: *quill*; *rachis*; *inferior* and *superior umbilici*; *vane* with *barbs*; under magnification NOTE *barbules* with *hooklets.*

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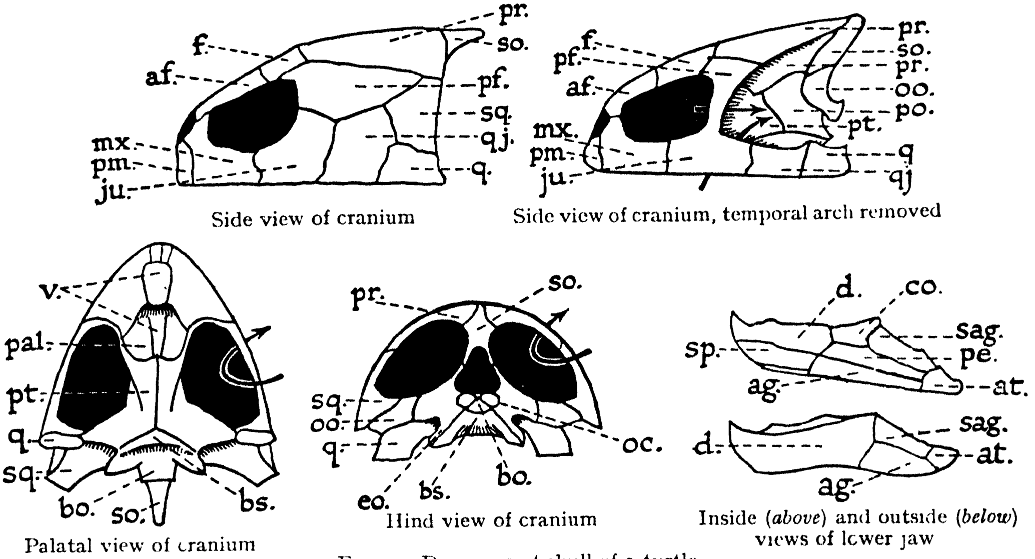
(*b*) *Contour feathers* from body with *aftershaft* and poorly developed *barbules.*

(*c*) *Down feathers* and *filoplumes.*

3. NOTE **skeleton.**

(*a*) **Skull**: absence of teeth; *beak* formed from *premaxillae*; *orbits* separated by *septum*; *brain-case* pushed back; single *occipital condyle*; lower jaw articulating with *quadrate*, which is movable relatively to the *squamosal*, resulting in a wide gape when the mouth opens.

(*b*) **Vertebral column**: *cervical vertebrae* consisting of *atlas*, *axis*, and twelve others with saddle-shaped *centra* giving great flexibility, *ribs* fused to *vertebrae* 3–11, *free ribs* on *vertebrae* 13 and 14; five *thoracic vertebrae*, first four fused together, last fused to *first lumbar*, jointed bony *ribs* fused ventrally to *sternum*, all *free ribs* except last bear *uncinate process*; six *lumbar vertebrae* fused with *last thoracic*, two *sacral*, and first five *caudal vertebrae* making strong extensive *sacrum*; six free *caudal vertebrae* and *pygostyle.*



Side view of cranium

Side view of cranium, temporal arch removed

Palatal view of cranium

Hind view of cranium

Inside (*above*) and outside (*below*) views of lower jaw

Fig. 34 Diagrams of skull of a turtle

af., prefrontal, ag., angular; at., articular; bo., basioccipital; bs., basisphenoid, co., coronoid; d., dentary; eo., exoccipital; f., frontal; ju., jugal, mx., maxilla, oc., occipital condyle, oo., opisthotic, pal., palatine; pe., prearticular; pf., postfrontal, pm., premaxilla; po., prootic; pr., parietal, pt., pterygoid; q., quadrate; qj., quadratojugal, sag., supra-angular; so., supraoccipital; sp., splenial, sq., squamosal; v., vomer

(*c*) **Pectoral girdle and limb**: *scapula*; *coracoid*; *clavicle*; *foramen* for *minor pectoral muscle*; *sternum* with *carina* for attachment of *major pectoral muscles*; *humerus*; *radius* and *ulna* which bear the *secondary remiges*; *carpals*; *carpo-metacarpus* and fused second and third *digits* which bear the *primary remiges*; *first digit* which bears the *bastard wing.* Divide the coracoid longitudinally with a hack-saw and NOTE the *pneumatic spaces.*

(*d*) **Pelvic girdle and limb**: fused *sacral vertebrae*; *ilium* connected with long stretch of *sacrum*; *ischium* and *pubis* without symphyses; *acetabulum*; *ilio-sciatic foramen*; *obturator fissure*; *femur*; *patella*; *tibia* fused with *fibula* and one row of *tarsals* to form *tibio-tarsus*; *distal tarsals* and *metatarsals* fused to form *tarso-metatarsus*; four *digits.*

MAMMALIA

Lepus cuniculus.[1] The rabbit.

1. NOTE external features: *head*; *neck*; *trunk*; *tail*; *fore limbs* with five *digits*; *hind limbs* with four *digits* (2–5); *nostrils*; *lips*; *eyes* with *lids* (*upper, lower,* and *nictitating*); *pinnae*; *vibrissae*; *anus*; *urino-genital opening*; *scrotal sacs* and *penis* in male; *mammae* in female.

2. Skin the side of the face. **Draw**: *masseter muscle*; *facial nerve*; *parotid gland*; *external auditory meatus*; *lacrymal* and *infraorbital glands* in orbit of eye.

3. (*a*) Cut through the muscles at the sides of the mouth. NOTE in mouth, when widely opened: heterodont *teeth*; tongue with taste *papillae*; *hard* and *soft palates*; *posterior* (*internal*) *nares*; *pharynx*; *opening* to oesophagus; *epiglottis*; *glottis.*

(*b*) Slit open the soft palate to reveal the *naso-pharynx* and the openings to the Eustachian tubes.

4. (*a*) Fasten the animal on its back to a dissecting board; skin the abdomen and remove the cut flaps of skin and fur. Open the muscular body wall with a longitudinal and several transverse cuts. NOTE organs as they lie *in situ*: *xiphoid cartilage*; *falciform ligament*; *liver*; *stomach*; *small intestine*; *caecum*; *colon*; *rectum*; *urinary bladder.*

(*b*) Deflect the liver and rearrange the stomach and small intestine in order to display the pancreas. **Draw** a plan: *oesophagus*; *cardiac* and *pyloric regions* of *stomach*; *spleen*; *duodenum*; *liver*; *gall bladder*; *bile duct*; *portal vein*; *pancreas* and *duct.*

(*c*) Deflect the alimentary canal to the animal's right. NOTE: left *kidney* and *suprarenal body*; *dorsal aorta*; *coeliac artery* dividing into *hepatic* and *lienogastric arteries*; *anterior mesenteric, renal,* and *posterior mesenteric arteries*; *inferior vena cava*; *renal veins*; left *splanchnic nerve*; *solar plexus.*

5. (*a*) Remove the alimentary canal from the body by cutting through the oesophagus and rectum. Ligature the oesophagus and rectum in order to prevent the contents escaping from the canal when removed. Ligature the portal vein in two places and cut between the ligatures. Spread out the canal on a dissecting board by cutting through the mesentery. **Draw** a plan: *oesophagus*; *cardiac* and *pyloric regions* of *stomach*; *pyloric sphincter*; *small intestine* ending in *sacculus rotundus*; *caecum*; *vermiform appendix*; *colon*; *rectum.*

(*b*) **Draw** a plan of organs in abdominal cavity after removal of alimentary canal: *diaphragm* with central *tendinous* and marginal *muscular portions*; *suprarenal bodies*; metanephric *kidneys*; *ureters*; *bladder*; *dorsal aorta*; *coeliac, anterior mesenteric, renal, genital, posterior mesenteric* and *common iliac arteries*; *inferior vena cava*; *renal, genital, external* and *internal iliac veins*; *fat.*

6. Cut through pubic symphysis with a strong pair of scissors and dissect out genital organs; in male pull testis out of scrotal sac and NOTE *gubernaculum.* **Draw male organs**: *testis*; *epididymis*; *vas deferens* (Wolffian duct); *uterus masculinus*; *urino-genital canal*; *perineal gland*; *penis.* **Draw female organs**: *ovary*; *Graafian follicles*; *oviduct* (Müllerian duct) with *internal opening*; *uterus*; *vagina*; *urino-genital canal*; *perineal gland.* **Draw** in both sexes: metanephric *kidney*; *ureter*; *bladder*; *rectum.*

7. (*a*) Skin the thorax and neck. Make a small incision with a scalpel through the

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[1] Also called *Oryctolagus cuniculus.*

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wall of the thorax first on the right then on the left side; note the flattening of the diaphragm as the right and left pleural cavities are exposed. Remove the sternum by cutting through the ribs. NOTE: *heart* in *pericardium*; *thymus gland*; *lungs*; *ribs* with *intercostal muscles*; *phrenic* and *vagus nerves.*

(*b*) Remove the thymus gland and the heart from the pericardium. NOTE: *auricles*; *ventricles*; *pulmonary arteries*; *arch* of *aorta* dividing into *innominate, right subclavian, right* and *left common carotid*, and *left subclavian arteries*; *superior venae cavae*; *subclavian, external jugular*, and *pulmonary veins*; *inferior vena cava*; ligamentous *ductus arteriosus* connecting aortic arch with pulmonary artery. **Draw** plans of the arterial and venous systems from this dissection and from Dissection 5 (*b*).

8. Remove the heart, cutting through the vessels some distance away. **Draw** ventral view: *right* and *left auricles*; *right* and *left ventricles*; *pulmonary artery*; *arch* of *aorta*; *right* and *left superior venae cavae*; *pulmonary vein.* **Draw** same parts in dorsal view.

9. **Heart of sheep.**

(*a*) NOTE in ventral view: *right* and *left auricles*; *right* and *left ventricles*, the latter can be felt to have a thick muscular wall; *fat*; *coronary artery*; *pulmonary artery*; *aorta*; *pulmonary vein*; *superior vena cava*; *inferior vena cava.*

(*b*) Cut through pulmonary artery and aorta to expose in each the three *semicircular valves.* Make longitudinal cuts to show interior of right and left sides of the heart. **Draw** interior view of right auricle and ventricle: *entrance* of *superior venae cavae* and *coronary vein*; *tricuspid valve*; *chordae tendineae*; *papillary muscles*; *fossa ovalis*; *columnae carneae*; *semilunar valve* in *pulmonary artery.* **Draw** interior view of left auricle and ventricle: thick *wall* of *ventricle*; glass rod pushed through aorta into ventricle; *mitral valve*; *chordae tendineae*; *papillary muscles*; *entrance* of *pulmonary vein* in left auricle.

10. Cut through the skin of the neck to expose the underlying structures. Make a small incision in the windpipe, insert the end of a pipette, and blow down, noting the inflation of the lungs. **Draw**: *posterior cornua* of *hyoid*; *larynx* slit open to show the *vocal cords*; *thyroid gland*; *trachea* with *cartilaginous rings*; *bronchi*; *oesophagus*; *external* and *internal carotid arteries*; *external* and *internal jugular veins*; *submaxillary* and *parotid* (*salivary*) *glands*; main *vagus nerve*; *superior* and *recurrent laryngeal, depressor, hypoglossal* (xii), and *cervical sympathetic nerves*; *vagus* and *superior cervical sympathetic ganglia.*

11. (*a*) **Draw** dorsal view of brain removed from skull and with one cerebral hemisphere pulled aside: *olfactory lobes*; *cerebral hemisphere* with *Sylvian fissure* dividing *temporal lobe* from *parietal* and *frontal lobes*; *corpus callosum*; *optic thalami*; *corpora quadrigemina*; *pineal body*; *cerebellum*; *medulla oblongata*; *fourth ventricle.*

(*b*) **Draw** ventral view of brain: *olfactory lobes*; *frontal* and *temporal lobes* divided by *rhinal fissure* from *hippocampal lobe*; *infundibulum*; *pituitary body*; *corpus albicans*; *crura cerebri*; *pons Varolii*; *medulla oblongata*; *optic chiasma* with *roots of optic nerve* (ii); roots of cranial nerves iii to xii.

12. **Skull of dog.**

(*a*) **Draw** side view: *premaxilla*; *maxilla*; *jugal* and *squamosal* forming *zygomatic* *arch*; *external auditory meatus*; *nasal*; *frontal*; *parietal*; *supra-occipital*; *exoccipital*; *occipital condyle*; *styloid process*; *lacrymal*; *palatine*; *pterygoid*; *alisphenoid*; *tympanic*; *optic foramen* in *orbito-sphenoid* for optic nerve (ii); *anterior foramen lacerum* between *orbito-sphenoid* and *alisphenoid* for oculomotor (iii), trochlear (iv), abducens (vi), and ophthalmic branch of trigeminal (v); *foramen rotundum* in *alisphenoid* for maxillary branch of trigeminal; *foramen ovale* between *alisphenoid* and *periotic* for mandibular branch of trigeminal.

(*b*) NOTE lower jaw consisting of *mandible* with *cylindrical condyle* for articulation with squamosal; dental formula, i (incisors) $\frac{3}{3}$, c (canines) $\frac{1}{1}$, p (premolars) $\frac{4}{4}$, m (molars) $\frac{2}{3}$; *carnassial teeth* last premolar in upper jaw and first molar in lower jaw; articulation of teeth forming knife-edge for cutting flesh.

(*c*) **Draw** palatal view: *premaxillae*; *maxillae*; *palatines*; *pterygoids*; *vomer*; *alisphenoids*; *basisphenoid*; *basioccipital*; *exoccipitals*; *occipital condyles*; *jugal* and *squamosal* forming *zygomatic arch* on each side; *tympanic bullae*; *glenoid fossae* for articulation of lower jaw; *foramen magnum* for spinal cord; *stylo-mastoid* foramen between *tympanic bulla* and *periotic* for facial (vii); *posterior foramen lacerum* between *periotic* and *exoccipital* for glossopharyngeal (ix), vagus (x), and spinal accessory (xi); *condylar foramen* in *exoccipital* for hypoglossal (xii).

(*d*) NOTE longitudinal vertical section of skull: *brain cavity*; *nasal passage*; *false* (*hard*) *palate* formed by *maxillae* and *palatines*; *mesethmoid*; *turbinals*; *cribriform plate*; *orbito-sphenoid*; *alisphenoid*; *periotic*; *foramen magnum.*

13. **Skeleton of rabbit.** Prepare as for frog's skeleton (page 106).

(*a*) **Skull**: compare with that of the dog; NOTE relative positions of the bones, dental formula $i\frac{2}{1}$, $c\frac{0}{0}$, $p\frac{3}{2}$, $m\frac{3}{3}$; chisel-edge of incisors worn sharp by attrition and ridge-like cusps of premolars and molars for grinding. Pull out one of the incisors and observe the opening of the pulp cavity which never closes since the tooth grows throughout life.

(*b*) **Vertebral column. Draw**: **Atlas** in front view; *neural spine, transverse process, facet* for occipital condyles. **Axis** in side view: *neural spine, odontoid process.* **Third cervical vertebra** in front view: *neural spine, neural arch, prezygapophyses, vertebral foramen, centrum, foramen* of *transverse process, cervical ribs.* **Fourth thoracic vertebra** in side view: *neural spine, prezygapophysis, postzygapophysis, facets* for tuberculum and capitulum of rib, *centrum, epiphysis.* **Second lumbar vertebra** in front view: *neural spine, metapophyses, prezygapophyses, neural arch, vertebral foramen, centrum, hypapophysis.*

(*c*) **Pectoral girdle and limb. Draw**: **Scapula** in side view: *blade, coracoid process, glenoid cavity, acromion, metacromion.* **Humerus** in front view: *head, tuberosity, deltoid ridge, olecranon ridge, trochlea.* **Radius and Ulna**: the latter with *olecranon process.* **Carpals, metacarpals, and phalanges.**

(*d*) **Pelvic girdle and limb. Draw**: *sacrum, ilium, ischium, acetabulum, obturator foramen.* **Femur** in front view: *head, great trochanter, lesser trochanter, third trochanter, condyles.* **Tibia and Fibula**: *cnemial edge* of tibia, *patella.* **Tarsals, including** *calcaneum,* **metatarsals, and phalanges.**

The method of attachment of vertebrae, girdles, and limbs should be observed in an articulated skeleton.

CHORDATA

BIOCHEMISTRY

PRACTICAL WORK

1. **Crystalloids.** Make a saturated solution of copper sulphate in distilled water at the room temperature. Observe some of the blue solution under the microscope; no trace of solid particles can be seen. Evaporate off some of the water and leave to crystallize, crystals of copper sulphate are recovered. *The solution of copper sulphate in water is a crystalloid.*

2. (*a*) **Colloids.** Pass carbon dioxide gas through lime-water in a test-tube. A *suspension* of calcium carbonate in water is obtained. On standing, the calcium carbonate falls to the bottom of the test-tube.

(*b*) Dilute a solution of Indian ink with water in a test-tube until quite transparent. Observe a sample under the microscope; the solid particles of Indian ink can be seen; they are not precipitated in the diluted solution. This is a *suspensoid sol.* [Continuous phase, *water*; disperse phase, *Indian ink particles.*] Notice under the microscope that the particles of Indian ink are in motion, from the continual bombardment by the molecules of water (*Brownian movement*).

(*c*) Shake up a little ether with distilled water in a test-tube; small drops of ether mix with the water to form an *emulsion.* On standing, the ether separates out and lies on top of the water. Fresh milk is a natural emulsion; on standing, the fats separate out.

(*d*) Stir 1 gm. of starch with a little cold water and add to 70 c.c. of boiling water, continue to boil for a few minutes with continual stirring. An *emulsoid* is produced since the starch will not separate out on cooling. [Continuous phase, *dilute solution of starch in water*; disperse phase, *concentrated solution of starch in water.*] One drop of the emulsoid, with iodine solution added, will show Brownian movement very well when viewed under the microscope.

(*e*) **Reversible Gel.** Dissolve some gelatine in warm water; a *colloid sol* is obtained. Evaporate off some of the water and leave to stand; the *sol* turns to a *colloid gel.* Add water and heat slightly; the *gel* turns back again to a *sol.*

3. **Separation of a Colloid from a Crystalloid** (Dialysis). Prepare a colloidal solution of starch in water. Stir 1 gm. of starch with a little cold water and add to 70 c.c. of boiling water, continue to boil for a few minutes with continual stirring. Mix the colloid with a little sodium chloride solution and pour into a parchment bag made from ordinary parchment paper—this makes a good semi-permeable membrane. Suspend the parchment bag in distilled water in a beaker. Leave for twenty-four hours. Test samples of the water in the beaker with silver nitrate and iodine solution. The crystalloid (sodium chloride) passes through the semi-permeable membrane but not the colloid (starch solution), which is said to be dialysed.

4. **Osmosis.** (*a*) Stretch a portion of pig's bladder (obtainable at a pork butcher's), which has been previously soaked in hot water, over the wide end of a thistle funnel and tie securely round the lip. Pour some treacle,[1] diluted with water and heated to make it more mobile, down the stem and into the funnel. Clamp the apparatus vertically so that the funnel end is in a beaker containing distilled water. The water will pass slowly through the semi-permeable membrane, causing the level of the diluted treacle to rise up the stem of the thistle funnel.

(*b*) Dissolve off the shells from two fresh eggs by immersing for a few hours in dilute hydrochloric acid. Place one egg in distilled water and the other in a concentrated solution of sodium chloride in water. The former egg will gradually swell and the latter will shrink (*plasmolysis*).

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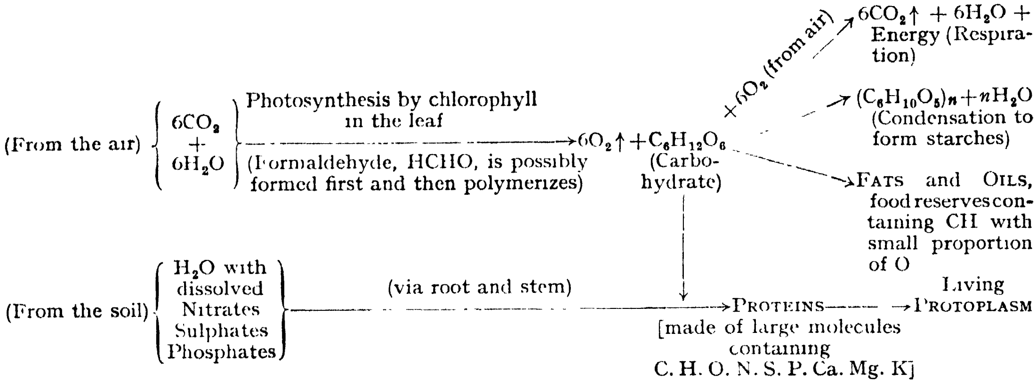
[1] Copper sulphate solution works equally well.

(*c*) The cells of a filamentous alga, such as *Spirogyra*, may be plasmolysed by placing on a microscope slide and surrounding with a 1 per cent calcium chloride solution. If the plasmolysis has not gone too far, the cells will recover when surrounded by water again.

FOOD RESERVES

The beginning and end of the principal chemical changes which take place in a holophytic plant may be represented as follows:



(From the air)
6CO₂ + 6H₂O
Photosynthesis by chlorophyll in the leaf
(Formaldehyde, HCHO, is possibly formed first and then polymerizes)
6O₂↑ + C₆H₁₂O₆ (Carbohydrate)
O₂ (from air)
6CO₂↑ + 6H₂O + Energy (Respiration)
(C₆H₁₀O₅)ₙ + nH₂O (Condensation to form starches)
FATS and OILS, food reserves containing CH with small proportion of O
(From the soil)
H₂O with dissolved Nitrates Sulphates Phosphates
(via root and stem)
PROTEINS
Living PROTOPLASM
[made of large molecules containing C. H. O. N. S. P. Ca. Mg. K]

TESTS FOR CARBOHYDRATES

Monosaccharides, $C_6H_{12}O_6$ (glucose, dextrose or grape sugar; galactose; mannose; laevulose, fruit sugar or fructose). These sugars are soluble in water and when heated with Fehling's solution produce a yellowish-red precipitate of cuprous oxide. Glucose is widely distributed as a food reserve in plants and serves as an attraction to animals in the juice of many fruits. Fehling's solution contains copper tartrate in alkaline solution, which is reduced by the monosaccharide. Fehling's solution may be used to detect the presence of monosaccharides in the urine of diabetic patients. The test can also be made quantitative.

Disaccharides, $C_{12}H_{22}O_{11}$ (sucrose or cane sugar; lactose or milk sugar; maltose or malt sugar). Sucrose and maltose are soluble in water and very slightly soluble in alcohol. Sucrose gives no reaction with Fehling's solution unless previously boiled with a dilute mineral acid or alkali, when it is hydrolysed to monosaccharides. When boiled with an acid, the excess acid must be neutralized with caustic soda before testing with Fehling's solution.

$$\underset{(\textit{sucrose})}{C_{12}H_{22}O_{11}+H_2O} \longrightarrow \underbrace{\underset{\textit{glucose}}{C_6H_{12}O_6}+\underset{\textit{fructose}}{C_6H_{12}O_6}}_{\substack{\text{mixture known as}\\ \textit{invertose}\text{ or invert}\\ \text{sugar}}}$$

Sucrose is the food reserve in the sugar-cane and beetroot. Maltose is found in a great many plants. Lactose is present in the milk of mammals; it will reduce Fehling's solution and hydrolyses to a mixture of glucose and galactose.

Polysaccharides $(C_6H_{10}O_5)_n$ (starch; dextrin; glycogen or animal starch; inulin; cellulose). Starch occurs in solid grains in all parts of the plant. Glycogen occurs in the liver of animals but rarely in plants. Inulin forms the food reserve in underground stems and roots of some plants (dahlia, Jerusalem artichoke, dandelion). Cellulose forms the cell walls of plants.

Starch with iodine and in the presence of water gives a deep blue colour due to a loose addition compound of starch and iodine. The colour is lost on heating but returns on cooling if not heated too long. Starch paste heated with a little sulphuric acid is turned first into dextrin (a transition compound also found in plants), then into maltose, and finally into glucose. If iodine is present during the heating process, the deep blue colour will turn violet, then red, due to the dextrin, and finally colourless when the hydrolysis is completed. It is better, however, to use the iodine as an external indicator of the course of the reaction, since it volatilizes during the heating process.

Inulin is soluble in water but not in alcohol. It gives no colour change with iodine, and is hydrolysed by heating with dilute acids to laevulose.

Cellulose is insoluble in water and alcohol, but soluble in a solution of zinc chloride. It stains iodine yellow and is hydrolysed by heating with concentrated sulphuric acid to dextrose.

TESTS FOR OILS

Oils and fats form the food reserves in many seeds (castor-oil and most nuts). Proteins are widely distributed in the food storage organs of plants and are the essential constituents of living protoplasm.

Oils. One per cent solution of osmic acid in water stains any tissue containing oils an intense black, due to the reduction of the osmic acid by olein, which is nearly always present in oils. The aniline dye Sudan 3 stains oils red. The oils will leave a greasy mark when smeared on paper, this can be dissolved off by ether, benzene, or chloroform, but not by water and rarely by alcohol.

Proteins. Three characteristic protein reactions are as follows:

(i) Xanthoproteic reaction; if a solution containing proteins is boiled with a few drops of nitric acid, a yellow colour or precipitate is produced. The solution should then be thoroughly cooled, when on adding ammonia, the colour will turn to a deeper yellow or orange.

(ii) Biuret reaction; if excess caustic soda is added to the solution of a protein and then *one* drop of 1 per cent copper sulphate solution, a violet or pink colour will be produced.

(iii) If a few drops of Millon's reagent are added to a solution of protein, a brick-red precipitate or solution will be obtained.

PRACTICAL WORK

5. **Monosaccharides.** Make a solution of glucose in water. Test a sample of the solution
   - (i) with iodine solution;
   - (ii) with Fehling's solution and heat.

Test thin slices of apple, carrot, and onion with Fehling's solution.

6. **Disaccharides.** Make a solution of cane sugar in water. Test a sample of the solution
   - (i) with iodine solution;
   - (ii) with Fehling's solution.

Next heat a sample with a little dilute hydrochloric acid, neutralize with caustic soda, and test with Fehling's solution.

Try these tests with thin slices of beetroot.

7. **Polysaccharides.** Make an emulsoid solution of starch in water by stirring 1 gm. of starch with cold water and adding to 70 c.c. of boiling water. Allow to boil for a few minutes and then leave to cool. Test samples of the emulsoid as follows:

(*a*) *Starch.*
   - (i) Add a little iodine solution, heat until the blue colour disappears. On cooling the colour returns. Reheat for a longer period and determine whether the colour returns.
   - (ii) With Fehling's solution a negative result is obtained.
   - (iii) Add a few drops of concentrated sulphuric acid and boil. Transfer drops of the hydrolysing mixture at intervals to drops of iodine solution on a white tile. When there is no change in colour on mixing a drop, neutralize with caustic soda and test with Fehling's solution.
   - (iv) Cut thin slices from a potato and spread out on a slide under the microscope. NOTE the starch grains; add a drop of iodine solution with a glass rod.

(*b*) ***Inulin.*** Cut thin slices from a dahlia root, boil with water in a beaker and test samples of the solution as follows:
   - (i) Add iodine solution.
   - (ii) Add Fehling's solution and heat.
   - (iii) Boil with a little dilute hydrochloric acid, neutralize with caustic soda, and test with Fehling's solution.

(*c*) *Glycogen.* Remove a little of the liver from a freshly killed rabbit or frog; cut up and boil with 60 per cent caustic soda solution (using equal number of gm. and c.c. of liver and potash) until all the tissue has disappeared. Neutralize with glacial acetic acid, filter. To the filtrate add 80 per cent alcohol until all the glycogen is precipitated. Decant the liquid and dry the glycogen between filter papers. Dissolve up the glycogen in warm water and test samples of the solution as follows:
   - (i) Add iodine solution.
   - (ii) Add Fehling's solution and heat.
   - (iii) Boil with a little dilute hydrochloric acid, neutralize with caustic soda, and test with Fehling's solution.

8. **Oils.**
   - (i) Remove the testa from castor-oil seeds, and smear a filter-paper with the contained endosperm. Leave one sample of paper to soak in water and another in benzene.

(ii) Cut thin sections from a seed, place on a slide under the microscope, and add a drop of 1 per cent osmic acid by means of a glass rod.

(iii) Shake up a few slices of the seed with Sudan 3 in a test-tube.

9. **Proteins.**

(i) Pound up some castor-oil seeds in a mortar; shake up with water. Filter and test the filtrate for proteins by the xanthoproteic reaction.

(ii) Test a portion of the white of an egg (unboiled) for proteins by the xanthoproteic and biuret reactions, and by warming with a few drops of Millon's reagent.

(iii) Heat a little urea[1] in a test-tube. It first melts giving off ammonia, then solidifies forming biuret. Dissolve this product in cold caustic soda, add one drop of 1 per cent copper sulphate solution. The characteristic colour of the biuret compound will be produced.

10. Test as many examples as possible of fruits, seeds, roots, tubers, bulbs, and corms, for **carbohydrates, oils,** and **proteins,** entering your results in the table below.

Tissue	*Monosaccharide*	*Disaccharide*	*Starch*	*Oils*	*Proteins*
Seed of Castor Oil (*Ricinus*)	absent	absent	absent	present	present

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[1] First synthesized by the German chemist Wöhler in 1828.

ENZYMES

Enzymes may be regarded as organic catalysts; they do not form a part of the products at the end of a reaction, and can influence a reaction in either direction.

Lipase	hydrolyses	fats	into	fatty acids and glycerol
Diastase	,,	starch	,,	glucose and maltose
Inulase	,,	inulin	,,	fructose
Invertase	,,	cane sugar	,,	glucose and fructose
Maltase	,,	maltose	,,	glucose
Cytase	,,	cellulose	,,	simpler carbohydrates
Zymase	decomposes	glucose	,,	ethyl alcohol and carbon dioxide

Amongst other enzymes, yeast cells contain zymase, invertase, and maltase. If the yeast cells be killed by heating with a mixture of alcohol and ether to a temperature of 30° C., the enzymes present are still chemically active and the mixture is known as ' zymin '.[1]

PRACTICAL WORK

11. A solution of invertase may be prepared from yeast as follows. Grind together in a mortar equal weights of yeast and silver sand, adding gradually 10 c.c. of water. After the mixture has been well ground up, add 50 c.c. of water slowly with thorough mixing. Filter through a Büchner funnel until a clear filtrate is obtained. Add a little of the filtrate, which contains invertase, to a solution of cane sugar in a test-tube. After allowing the mixture to stand for a few minutes, test with Fehling's solution for the presence of monosaccharides.

The saliva and pancreatic juices contain **ptyalin**, which is an enzyme probably identical with **diastase**, since it can turn starch into maltose and glucose.

12. Make a starch paste solution and divide it into two parts in test-tubes. To one add saliva and to the other a portion of a rabbit's pancreas. Test portions at intervals by mixing with drops of iodine solution on a white tile. When no colour change takes place on mixing, test with Fehling's solution.

CHLOROPHYLL

A solution of chlorophyll may be obtained by heating up some green leaves with 95 per cent alcohol, or 80 per cent acetone on a water bath. If the leaves are fresh they should first be killed by immersion in hot water, but dried leaves work equally well. A very concentrated solution may be obtained by heating the leaves with alcohol in a reflux condenser for several hours.

DEMONSTRATION EXPERIMENTS

13. (*a*) Observe the colour of the filtered chlorophyll solution when placed in a flask. It is green by reflected light and red by transmitted light.

(*b*) **Spectroscopic Examination.** A very concentrated solution transmits light only in the green and extreme red. When diluted with more 95 per cent alcohol there is a well-marked absorption band in the red (centre corresponding to wavelength 660). On adding caustic potash solution, the single band divides up into two with a distinct part of the red spectrum showing between. This is a very characteristic reaction of chlorophyll. The two bands can be made to join up again into a single but fainter band by adding acetic acid to neutralize the alkali.

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[1] Full directions for this preparation will be found in *Practical Plant Biochemistry*, by M. W. Onslow.

Haemoglobin

Blood begins to clot as soon as shed, but remains liquid for a long time in the intact vessels of a dead animal. Clotting is due to the precipitation of the protein *fibrin* which entangles the red and white corpuscles. Defibrinated blood containing red and white corpuscles suspended in plasma may be obtained by shaking up some blood drawn from a freshly killed animal with glass beads in a flask. The fibrin adheres to the glass beads and the defibrinated blood may be decanted.

PRACTICAL WORK

14. **Iron** may be detected in blood as follows. Place a drop of defibrinated blood in a crucible and heat, at first gently and then strongly to dull red heat. Dissolve the residue with concentrated hydrochloric acid and add a few drops of potassium ferrocyanide. The deep blue colour of ferric ferrocyanide will be produced (*Prussian blue*).

DEMONSTRATION EXPERIMENTS

15. (*a*) Oxyhaemoglobin may be obtained from haemoglobin by shaking up defibrinated blood in a test-tube with plenty of air. It may be reduced by heating with a few drops of ammonium sulphide to 50° C., when it turns to the deeper red colour of the haemoglobin.

(*b*) **Spectroscopic Examination.** Defibrinated blood containing oxyhaemoglobin will show two marked absorption bands between the red and green (centres corresponding to wavelengths 578 and 542). When reduced, the two bands join to form one broad but fainter band (centre corresponding to wavelength 555).

16. If a live tadpole be placed on a dry microscope slide so that its tail lies flat, the circulation of the red blood corpuscles in the capillaries of the tail may be readily observed under a microscope.

APPENDIX A

LIST OF REAGENTS

Alcohol. Commercial methylated spirit = 95%. To prepare weaker solutions this is diluted with distilled water.

Example. To prepare 60% alcohol from standard 90% alcohol.

$$\begin{array}{c} 90 \\ \underline{60} \\ \underline{30} \end{array}$$

60 vols. of standard 90% alcohol + 30 vols. of water will give 90 vols. of required 60% alcohol.

FIXING REAGENTS

Bouin's Fluid.

Saturated solution picric acid in water	75 c.c.
40% formalin	25 c.c.
Acetic acid	5 c.c.

Of general application for animal material. Rapid and penetrating.

Corrosive Sublimate and Acetic Acid.

Corrosive sublimate ($HgCl_2$)	3 gm.
Glacial acetic acid	5 c.c.
70% alcohol or water	100 c.c.

Best used hot (85° C.). Of general application for animal material.

Flemming's Fluid.

A	1% chromic acid	25 c.c.
	1% acetic acid	10 c.c.
	Water	55 c.c.
B	1% osmic acid	10 c.c.

Keep A made up and mix with B when required for use, as the mixture does not keep for any length of time. Of general application for fixing and hardening plant material.

Formal Alcohol.

10% formalin	50 c.c.
70% alcohol	50 c.c.

Good for fixing and preserving plant and animal tissues.

PRESERVING REAGENTS

Alcohol. 90% or 95% alcohol may be used to fix and preserve tissue where it is not required to retain the cell contents. It is better when preserving material for a long period to mix 95% alcohol with equal volumes of glycerine to prevent the tissues becoming hard and brittle.

Formalin. Commercial formalin = 40% formaldehyde. Mix 1 vol. commercial formalin with 20 vols. water.

APPENDIX A

Hardening Reagents

Müller's Fluid.

Potassium dichromate	25 gm.
Sodium sulphate	10 gm.
Water	1 litre

Picric Acid. Make saturated solution of picric acid crystals in water. Allow to stand and filter before use. May also be used to stain chitin.

STAINS

Preparation of weak alcoholic solutions of the Aniline Dyes. Place dye in glass bottle with well-fitting stopper and add enough 90% alcohol to make a saturated solution; this *stock* solution will keep a long time. In order to prepare a *staining* solution, filter stock solution into distilled water until the mixture becomes just opaque. Dilute staining solutions are more efficient than concentrated ones. For Sudan 3, dissolve 0·01 gm. of the stain in 5 c.c. 90% alcohol and add 5 c.c. glycerine.

Aniline (hydro)chloride. Make a saturated solution in distilled water and acidify with a few drops of hydrochloric acid. Prepare aniline sulphate in the same way, acidifying with sulphuric acid.

Borax Carmine (Grenacher's).

Carmine	3 gm.
Borax	4 gm.
Distilled water	100 c.c.

Dissolve by gently heating the borax in water and add the carmine. Add 100 c.c. of 70% alcohol, allow to stand two or three days, then filter.

Carbol Fuchsin (Ziehl-Neelsen).

5% carbolic acid	100 c.c.
Saturated alcoholic solution of fuchsin	10 c.c.

Dilute about 4 times with distilled water when required for use.

Carbol Methylene Blue (Kühne).

Methylene blue	1·5 gm.
Absolute alcohol	10 c.c.
5% carbolic acid	100 c.c.

Delafield's Haematoxylin. Dissolve 1 gm. haematoxylin in 6 c.c. absolute alcohol and add drop by drop to 100 c.c. saturated solution of ammonia alum in water. Expose to light and air for a week and then filter. To the filtrate add 25 c.c. glycerine and 25 c.c. methylated spirits. Filter and keep for about two months before using.

Ehrlich's Acid Haematoxylin. Dissolve 2 gm. haematoxylin in 100 c.c. absolute alcohol, then add 100 c.c. water, 100 c.c. glycerine, 10 c.c. glacial acetic acid, and alum in excess. Allow the mixture to ripen in the light by leaving in a bottle for several weeks, occasionally removing stopper, replacing, and shaking up with a little air. When ripe the stain darkens, and if kept well stoppered remains at constant strength for years.

Picro-Carmine (Ranvier's). Add strong solution of carmine in ammonia to a saturated solution of picric acid in water until the saturation point is reached. Evaporate down to ⅓ of the original volume. Filter and evaporate filtrate to dryness. The picro-carmine obtained as red crystals may then be dissolved in distilled water. One per cent solution should be used for staining.

Schultze's Solution (Chlor-Zinc-Iodine).

A	Zinc	110 gm.	Evaporate to half original volume and add a little zinc to neutralize all the acid
	Hydrochloric acid (pure)	300 c.c.	
B	Iodine	0·15 gm.	
	Potassium iodide (dissolved in as little water as possible)	12 gm.	

Mix A and B, filter through glass wool and keep in the dark.

MISCELLANEOUS REAGENTS

Berlese Fluid.

Distilled water	20 c.c.
Chloral hydrate	160 gm.
Gum arabic	15 gm.
Glucose syrup	10 gm.
Acetic acid	5 gm.

Clearing and mounting fluid for small insects and their mouth parts.

Fehling's Solution.

A	Copper sulphate	35 gm.
	Water	1 litre
B	Sodium potassium tartrate (Rochelle salt)	173 gm.
	Caustic soda	70 gm.
	Water	1 litre

Keep as two solutions, A and B. When required for use mix equal volumes of A and B.

Iodine Solution (for starch tests and staining).

Iodine	5 gm.
Potassium iodide	10 gm.
Water	1 litre

Dissolve the potassium iodide in water and then add the iodine.

Pasteur's Culture Solution (for Fungi).

Potassium phosphate	1·0 gm.
Calcium phosphate	0·1 gm.
Magnesium sulphate	0·1 gm.
Ammonium tartrate	5·0 gm.
Cane sugar	75·0 gm.
Water	450 c.c.

Physiological or **Normal Salt Solution.** 7·5 gm. sodium chloride dissolved in 1 litre of water.

APPENDIX B

Material for dissection, etc., may be obtained from:

Botanical Supply Agency, Rhydyfelin, Aberystwyth (botanical).
Marine Biological Laboratory, Citadel Hill, Plymouth (marine specimens).
National Collection of Type Cultures, Lister Institute, Chelsea Bridge Road, London, S.W.3 (fungi and bacteria).
E. Gerrard and Sons, 61 College Place, Camden Town, London, N.W.1 (zoological and botanical specimens, also models, skeletons, etc.).

Stains and reagents for microscopy may be obtained from:

British Drug Houses, Ltd., Graham Street, London, N.1.
Harrington Bros., 53 City Road, London, E.C.1.
Hopkin and Williams, Ltd., 16 Cross Street, Hatton Garden, London, E.C.1; and any other reliable firm of chemical manufacturers.

Microscopes and accessories, dissecting instruments, etc., may be obtained from:

Chas. Baker, 244 High Holborn, London, W.C. 1.
R. and J. Beck, Ltd., 69 Mortimer Street, London, W.1.
W. Watson and Sons, Ltd., 313 High Holborn, London, W.C. 1.

The following can supply dissecting instruments, reagents for microscopy, prepared slides, etc., from comprehensive stocks of biological apparatus:

Baird and Tatlock, Ltd., 14–17 Cross Street, Hatton Garden, London, E.C.1.
Flatters and Garnet, Ltd., 309 Oxford Road, Manchester 13.
Philip Harris and Co., Ltd., 144 Edmund Street, Birmingham.

W. and G. Foyle, 119–125 Charing Cross Road, London, W.C. 2, have the agency for Dr. Paul Pfurscheller's zoological wall-diagrams.

Sidgwick and Jackson, Ltd., 44 Museum Street, London, W.C.1, are the publishers of a series of coloured wall-diagrams of useful zoological types.

GLOSSARY OF TECHNICAL TERMS

Abbreviations

dim., diminutive
Gk., Greek
Fr., French
Lat., Latin

A, Gk. *a,* without
Abducens, Lat. *abduco,* I lead away
Acetabulum, Lat., used by *Pliny* to mean the socket for the hip bone (literally, ' cup for vinegar ')
Achene, Gk. *a,* without; *chainein,* to gape open
Aciculum, Lat. *acicula,* small needle
Acromion, Gk. *akros,* tip; *omos,* the shoulder
Actinomorphic, Gk. *aktis,* ray; *morphe,* shape
Adipose, Lat. *adeps,* fat
Adrenal, Lat. *ad,* near; *ren,* kidney
Aecidiospore, Lat. *aecidium,* cup; Gk. *sporos,* seed
Aërobe, Gk. *aer,* air; *bios,* life
Afferent, Lat. *ad,* to; *fero,* I carry
Alisphenoid, Lat. *ala,* wing; Gk. *sphen,* wedge; *eidos,* form.
Alveolus, Lat. small channel
Anabolism, Gk. *anabole,* that which is built up
Anapophysis, Gk. *ana,* up; *apo,* from; *physis,* origin
Androecium, Gk. *aner,* male; *oikion,* dwelling
Androgonidium, Gk. *aner*; *gonidion,* small seed
Anemophilous, Gk. *anemos,* wind; *philos,* loving
Annulus, Lat. ring
Anterior, Lat. in front
Anther, Gk. *anthos,* flower
Antheridiophore, Gk. *anthos*; *idion,* dim.; *pherein,* to bear
Antheridium, Gk. *anthos*; *idion*
Apocarpous, Gk. *apo,* away from; *karpos,* fruit
Archegoniophore, Gk. *arche,* beginning; *gonos,* offspring; *pherein,* to bear.
Archegonium, Gk. *arche*; *gonos*
Aster, Gk. star
Axon, Gk. axis

Bacillus, Lat. dim. of *baculus,* rod
Basipterygium, Gk. *basis,* base; *pterygion,* little wing
Biology, Gk. *bios,* life; *logos,* discourse
Blastocoel, Gk. *blastos,* budding; *koilos,* hollow
Blastoderm, Gk. *blastos*; *derma,* skin
Blastula, Gk. dim. of *blastos*
Brachial, Lat. *brachium,* arm
Branchial, Gk. *branchia,* gills
Branchiostegite, Gk. *branchia*; *stege,* roof
Bronchus, Gk. *bronchos,* windpipe

Caecum, Lat. *caecus,* blind
Calcaneum, Lat. heel
Callosum, Lat. *callosus,* thick-skinned
Calyptera, Gk. *kalyptra,* covering
Calyx, Gk. *kalyx,* husk
Cambium, Lat. *cambio,* I exchange
Cardo, Lat. hinge
Carina, Lat. keel
Carotid, Gk. *karotides,* used by *Galen* to mean the neck arteries
Carpals, Lat. *carpus,* wrist
Carpels, Gk. *karpos,* fruit
Caruncle, Lat. *caruncula,* little piece of flesh
Caryopsis, Gk. *karyon,* nut; *opsis,* appearance
Caudal, Lat. *cauda,* tail
Cava, Lat. hollow
Cell, Lat. *cella,* small compartment
Centrosome, Gk. *kentron,* centre; *soma,* body
Centrum, Gk. *kentron*
Cephalate, Gk. *kephale,* head
Cerato, Gk. *keras,* horn
Cercaria, Gk. *kerkos,* tail
Cerci anales, Gk. *kerkos*; Lat. *analis,* anal
Cerebrum, Lat. brain; **Cerebellum,** dim. form.
Chela, Gk. *chele,* claw
Chiasma, Gk. *chi,* cross-shaped
Chloragogenous, Gk. *chloros,* green or yellow; *genos,* producing
Chlorophyll, Gk. *chloros*; *phyllon,* leaf
Chloroplast, Gk. *chloros*; *plastos,* moulded
Chromatin, Gk. *chromatinos,* coloured
Chromatophore, Gk. *chroma,* colour; *pherein,* to bear
Chromosome, Gk. *chroma*; *soma,* body

Cilium, Lat. eyelash
Cirrus, Lat. tuft of hair
Clavicle, Lat. *clavis,* key
Clitellum, Lat. saddle
Cloaca, Lat. the main sewer under Rome
Clypeus, Lat. shield
Cnemial, Gk. *kneme,* lower leg
Cnidoblast, Gk. *knide,* nettle; *blastos,* budding
Cnidocil, Gk. *knide*; Lat. *cilium,* eyelash
Coarctate, Lat. *coarctare,* to press together
Cochlea, Gk. *kochlias,* snail
Coelom, Gk. *koilon,* cavity
Coenobium, Gk. *koinos,* in common; *bios,* life
Coenocyte, Gk. *koinos*; *kytos,* cell
Collenchyma, Gk. *kolla,* glue; *enchyma,* infusion
Colloid, Gk. *kolla*
Columella, Lat. *columen,* column
Condyle, Gk. *kondylos,* knuckle
Conidiophore, Gk. *konis,* dust; *pherein,* to bear
Coracoid, Gk. *korax,* crow; *eidos,* form
Cornea, Lat. *corneus,* horny
Corolla, Lat. small crown
Coronoid, Gk. *koronos,* curved
Cortex, Lat. bark
Cotyledon, Gk. *kotyledon,* sucker
Coxa, Lat. hip
Cranium, Lat. top part of the skull
Crenate, Lat. *crena,* notch
Cribriform, Lat. *cribrum,* sieve; *forma,* shape
Crura, Lat. *crus,* leg
Ctenoid, Gk. *kteis,* comb; *eidos,* form
Cyst, Gk. *kyste,* bladder
Cytoplasm, Gk. *kytos,* cell; *plasma,* moulded

Deciduous, Lat. *decido,* I fall off
Dehiscence, Lat. *dehisco,* I yawn or gape
Dendrite, Gk. *dendron,* tree
Desmogen, Gk. *desmos,* bond; *genos,* origin
Di, Gk. double
Diastema, Gk. interval or gap
Dimorphism, Gk. *di,* double; *morphe,* shape or form
Dioecious, Gk. *di*; *oikion,* dwelling
Diploid, Gk. *diplos,* twofold
Diverticulum, Lat. *divertus,* turned away
Ductus Cuvieri, named after Baron *Cuvier* (1769–1832), a French anatomist
Duodenum, Lat. *duodeni,* by twelves. So called from being about the length of twelve fingers' breadths

Ecdysis, Gk. *ek,* off; *dyo,* I shed
Ectoderm, Gk. *ektos,* outside; *derma,* skin
Ectoplasm, Gk. *ektos*; *plasma,* that which is formed
Efferent, Lat. *effero,* I lead out of
Elater, Gk. driver
Elytra, Gk. *elytron,* cover or sheath
Embryo, Gk. *embryon,* embryo
Endoderm
Endodermis Gk. *endon,* within; *derma,* skin
Endoplasm, Gk. *endon*; *plasma,* that which is formed
Endosperm, Gk. *endon*; *sperma,* seed
Enteron, Gk. gut
Entomophilous, Gk. *entomon,* insect; *philos,* loving
Enzyme, Gk. *en,* in; *zyme,* yeast or leaven. Term introduced by *Kühne* in 1878
Epiblast, Gk. *epi,* on; *blastos,* budding
Epicotyl, Gk. *epi*; *kotyledon,* cotyledon or sucker
Epiderm
Epidermis Gk. *epi*; *derma,* skin
Epigeal, Gk. *epi*; *ge,* earth
Epigynous, Gk. *epi*; *gyne,* woman
Epiphysis, Gk. *epi*; *physis,* growth
Epithelium, Gk. *epi*; *thele,* teat
Ethmoid, Gk. *ethmos,* sieve
Etiolation, Fr. *étiolé,* blanched
Eustachian tubes, named after *Eustachio,* an Italian physician of the sixteenth century
Exarate, Lat. *exaratus,* ploughed up
Excretion, Lat. *ex,* out of; *cresco,* I grow

Falciform, Lat. *falx,* sickle; *forma,* shape
Fascicular, Lat. *fasciculus,* small bundle
Femur, Lat. thigh
Fibula, Lat. clasp
Fission, Lat. *findo,* I cleave
Flagellum, Lat. small whip

Galea, Lat. helmet
Galen (*c.* A.D. 130–200), Greek physician and teacher of medical science
Gamete, Gk. *gamete,* spouse
Gametogenesis, Gk. *gamete*; *genesis,* producing
Gametophyte, Gk. *gamete*; *phyton,* plant
Ganglion, Gk. *ganglion,* swelling
Gastrula, Gk. *gaster,* belly
Gemma, Lat. bud
Gene, Gk. *genos,* origin or birth
Genus, Gk. *genos,* race
Glochidium, Gk. *glochis,* arrow point; *idion,* dim.
Glossopharyngeal, Gk. *glossa,* tongue; *pharynx,* gullet

Gluma, Lat. husk
Gonophore, Gk. *gonos*, seed; *pherein*, to bear
Gonotheca, Gk. *gonos*; *theke*, box
Gubernaculum, Lat. guidance
Gula, Lat. throat
Gynoecium, Lat. *gynaeceum*, women's apartments in a house
Gynogonidium, Gk. *gyne*, woman; *gonidion*, small seed

Haemoglobin, Gk. *haima*, blood; Lat. *globulus*, drop
Haploid, Gk. *haplous*, one fold
Haustorium, Lat. *haurire*, to drink
Hepatic, Gk. *hepar*, liver
Heterogeny, Gk. *heteros*, different; *genos*, origin
Hilum, Lat. a little thing
Histology, Gk. *histos*, web; *logos*, discourse
Holophyte, Gk. *holos*, whole; *phyton*, plant
Holozoite, Gk. *holos*; *zōon*, animal
Hormone, Gk. *hormon*, starting
Hyaline, Gk. *hyalos*, glass
Hydrophyte, Gk. *hydor*, water; *phyton*, plant
Hydrotheca, Gk. *hydor*; *theke*, box
Hymenium, Gk. *hymen*, membrane
Hyoid, Gk. *hyoeides*, shaped like a letter Y
Hypha, Gk. *hyphe*, web
Hypocotyl, Gk. *hypo*, under; *kotyledon*, cotyledon or sucker
Hypogeal, Gk. *hypo*; *ge*, earth
Hypogenous, Gk. *hypo*; *gyne*, woman
Hypoglossal, Gk. *hypo*; *glossa*, tongue
Hypophysis, Gk. *hypo*; *physis*, growth

Incus, Lat. anvil
Indusium, Lat. *induere*, to put over
Infundibulum, Lat. *in*, into; *fundibulum*, little funnel
Innominate, Lat. *innominatus*, unnamed
Invaginate, Lat. *in*, into; *vagina*, sheath. Hence to put into, or as into, a sheath.
Involucre, Lat. *involucrum*, cover
Iris, Gk. bright circle.
Ischium, Gk. *ischion*, hip

Jugal, Lat. *jugum*, yoke. Later used in anatomy as pertaining to the cheekbone.
Jugular, Lat. *jugulum*, throat

Karyokinesis, Gk. *karyon*, nut or nucleus; *kinesis*, movement
Katabolism, Gk. *kata*, down; *bole*, throwing

Labrum, Lat. lip
Lacinia, Lat. flap
Lacuna, Lat. cavity or opening
Lamella, Lat. small plate
Larva, Lat. mask
Leucocyte, Gk. *leukos*, clear or white; *kytos*, cell
Lien, Lat. spleen
Ligula, Lat. little tongue
Linin, Gk. *linon*, thread
Lodicule, Lat. *lodicula*, coverlet
Lumbar, Lat. *lumbus*, loin

Malleus, Lat. hammer
Manubrium, Lat. handle
Medulla oblongata, Lat. elongate medulla
Medullated, Lat. *medulla*, marrow
Meganucleus, Gk. *megas*, great; Lat. *nucleus*, nut or nucleus
Meiosis, Gk. reduction
Mentum, Lat. chin
Meristematic, Gk. *meristos*, divisible
Mesentery, Gk. *mesos*, middle; *enteron*, entrail
Mesoblast, Gk. *mesos*; *blastos*, budding
Mesoderm, Gk. *mesos*; *derma*, skin
Mesogloea, Gk. *mesos*; *gloea*, glue
Mesophyll, Gk. *mesos*, *phyllon*, leaf
Metabolism, Gk. *metabole*, change
Metacarpals, Gk. *meta*, beyond; *karpos*, wrist
Metamorphosis, Gk. transformation
Metatarsals, Gk. *meta*, beyond; *tarsos*, ankle
Micropyle, Gk. *mikros*, little; *pyle*, gate
Mitosis, Gk. *mitos*, thread
Monoecious, Gk. *monos*, single; *oikion*, dwelling
Monopodial, Gk. *monos*; *pous*, foot
Morphology, Gk. *morphos*, form or shape; *logos*, discourse
Mycelium, Gk. *mykes*, fungus
Myoneme, Gk. *mus*, muscle; *nema*, thread

Nares, Lat. nostrils
Nematocyst, Gk. *nema*, weaving; *kyste*, bladder
Nephridium, Gk. *nephros*, kidney
Nephrostome, Gk. *nephros*; *stoma*, mouth or opening
Neurilemma, Gk. *neuron*, nerve; *eilema*, sheath
Neuron, Gk. nerve
Notochord, Gk. *noton*, back; *chorde*, cord
Notum, Gk. *noton*
Nucellus, Lat. dim. of *nux*, nut
Nucleus, Lat. dim. *nucleolus*, kernel

Obdurator, Lat. *obduro,* I harden
Obtect, Lat. *obtegere,* to cover
Occipital, Lat. *occiput,* back part of head
Ocellus, Lat. dim. of *oculus,* eye
Odontoid, Gk. *odous,* tooth
Omosternum, Gk. *omos,* shoulder; *sternon,* breast
Oocyte, Gk. *oon,* egg; *kytos,* cell
Oogenesis, Gk. *oon*; *genesis,* birth
Oogonium, Gk. *oon*; *gonos,* seed
Operculum, Lat. cover
Osmosis, Gk. *osmos,* pressure
Ostium, Lat. door
Ovum, Lat. egg. **Ovule,** dim. form

Palea, Lat. chaff
Pappus, Gk. *pappos,* old man
Para, Gk. alongside of, contrary to
Parasite, Gk. *para*; *sitos,* feeding
Parenchyma, Gk. *para*; *enchyma,* infusion
Parietal, Lat. *paries,* partition
Parthenogenesis, Gk. *parthenos,* virgin; *genesis,* birth
Parthenogonidium, Gk. *parthenos*; *gonidion,* small seed
Perianth, Gk. *peri,* around; *anthos,* flower
Perigynous, Gk. *peri*; *gyne,* female
Peripheral, Gk. *peripheres,* moving around
Perisarc, Gk. *peri,* around; *sarx,* flesh
Peristalsis, Gk. *peri*; *stalsis,* constriction
Peritoneum, Gk. *peritonaeon,* membrane stretched over
Phaeoplast, Gk. *phaios,* dusky; *plastos,* moulded
Phagocyte, Gk. *phagein,* to eat; *kytos,* cell
Phalanges, Gk. *phalanx,* straight line
Phellogen, Gk. *phellos,* cork; *genos,* origin
Phloem, Gk. *phloios,* bark
Photosynthesis, Gk. *phos,* light; *synthesis,* building up
Phrenic, Gk. pertaining to the diaphragm
Pileus, Lat. cap
Piliferous, Lat. *pilus,* hair; *ferre,* to carry
Pinna, Lat. feather or wing
Pituitary, Lat. *pituita,* phlegm or mucus
Plasma, Gk. mould or matrix
Pliny (A.D. 23–79), Roman writer on natural history
Podical, Gk. *pous,* foot
Polyp, Gk. *polypous,* many-footed
Proboscis, Gk. *pro,* in front; *bosko,* I feed
Propterygium, Gk. *pro*; *pterygion,* little wing
Protandrous, Gk. *protos,* first; *aner,* male
Prothallus, Gk. *pro,* before; *thallos,* young shoot
Protonema, Gk. *protos,* first; *nema,* weaving
Protoplasm, Gk. *protos*; *plasma,* mould or matrix
Pseudonavicella, Gk. *pseudes,* false; Lat. *navicella,* little boat
Pseudopodium, Gk. *pseudes*; *pous,* foot
Pterygoid, Gk. *pteryx,* wing; *eidos,* form
Pygostyle, Gk. *pyge,* rump; *stylos,* column
Pyrenoid, Gk. *pyren,* fruit stone; *eidos*

Quadrate, Lat. *quadratus,* square

Racemose, Lat. *racemus,* bunch of grapes
Radicle, Lat. *radix,* root
Ramus, Lat. branch
Rectus, Lat. straight
Restiform, Lat. *restis,* rope; *forma,* shape
Reticulated, Lat. *reticulum,* net
Retina, Lat. *retineo,* I retain
Rhizoid, Gk. *rhiza,* root; *eidos,* form
Rhizome, Gk. *rhizoma,* root
Rostellum, Lat. little beak-like process

Saprophyte, Gk. *sapros,* rotten: *phyton,* plant
Sarcolemma, Gk. *sarx,* flesh; *lemma,* skin
Scalariform, Lat. *scalarium,* ladder; *forma,* shape
Scaphognathite, Gk. *skaphe,* boat; *gnathos,* jaw
Scapula, Lat. shoulder blade
Schizogamy, Gk. *schizo,* I cleave; *gamos,* marriage
Schizozoite, Gk. *schizo*; *zōon,* animal
Sclerenchyma, Gk. *skleros,* hard; *enchyma,* infusion
Sclerite, Gk. *skleros*
Scutellum, Lat. small shield
Secretion, Lat. *secretus,* separated
Serum, Lat. whey
Siliqua, Lat. pod
Soma, Gk. body
Sorus, Gk. *soros,* pile
Spermatozoid, Gk. *sperma,* seed; *zōon,* animal; *eidos,* form
Spermatozoon, Gk. *sperma*; *zōon*
Spireme, Gk. *speirema,* coil
Sporangium, Gk. *sporos,* seed; *angeion,* vessel
Sporogonium, Gk. *sporos*; *gonos,* offspring
Sporophyte, Gk. *sporos*; *phyton,* plant
Squamosal, Lat. *squama,* scale of fish or serpent
Stapes, Lat. stirrup

Staphylococcus, Gk. *staphyle,* bunch of grapes; *kokkos,* berry or seed
Stigma, Gk. prick or mark
Stoma, Gk. mouth. Plural, *stomata*
Streptococcus, Gk. *streptos,* pliant; *kokkos,* berry or seed
Suture, Lat. *sutura,* sewing
Symbiosis, Gk. *syn,* together; *bios,* life
Symphysis, Gk. *syn*; *physis,* growing
Synapsis, Gk. *syn*; *apsis,* fitting
Syncarpous, Gk. *syn*; *karpos,* fruit
Syncytium, Gk. *syn*; *kytos,* cell
Synergidae, Gk. *synergos,* co-operator
Syngamy, Gk. *syn*; *gamos,* marriage

Teleutospore, Gk. *teleute,* end; *sporos,* seed
Telson, Gk. limit
Testa, Lat. shell
Thalamencephalon, Gk. *thalamos,* receptacle; *enkephalos,* brain
Trichocyst, Gk. *trix,* hair; *kystis,* bladder
Trigeminal, Lat. *trigeminus,* threefold
Trophozoite, Gk. *trophos,* rearing or feeding; *zōon,* animal
Tropism, Gk. *tropos,* turning
Typhlosole, Gk. *typhlos,* blind; *solen,* channel

Uncinate, Lat. *uncus,* hook

Vacuole, Lat. *vacuus,* empty
Vagina, Lat. sheath
Vas, Lat. vessel
Vena, Lat. vein
Venter, Lat. belly
Vermiform, Lat. *vermis,* worm; *forma,* shape
Vesicula, Lat. *vesica,* bladder
Vulgaris, Lat. common

Xanthoproteic, Gk. *xanthos,* yellow; *proteus,* the changeable one
Xerophyte, Gk. *xeros,* dry; *phyton,* plant
Xiphisternum, Gk. *xiphos,* sword; *sternon,* breast
Xylem, Gk. *xylon,* wood

Zygantrum, Gk. *zygon,* yoke; *antron,* hole
Zygapophysis, Gk. *zygon*; *apophysis,* offshoot
Zygomorphic, Gk. *zygon*; *morphe,* shape (bilateral)
Zygote, Gk. *zygotes,* yoked

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